CORRIGENDA.

June, 1940, Journal:—"Highway Transition-Curves: a New Basis for Design." By H. A. Warren, M.Sc. (Eng.), Assoc. M. Inst. C.E.

p. 379, line 20. *For* $\frac{2}{10}$ *read* $\frac{2{\cdot}5}{10}$

p. 380, line 19. *For* 6·1 *read* 6 : 1.

p. 380, line 27. *For* 275×10^{-9} *read* $2{\cdot}75 \times 10^{-9}$,

p. 382, line 3. *For* $\frac{2}{3{\cdot}50^2}$ *read* $\frac{3 \times 50^2}{2}$.

On the motion of the President, it was resolved:—

"That the President and Council and the members of The Institution of Civil Engineers desire to record the deep regret with which they have learned of the deaths of

William Barton Worthington, D.Sc., a distinguished and honoured Past-President, whose long and valued service as a Member of Council was recognized by his election as President in 1921;

and

Griffith John Griffiths, whose service as a Member of Council since November 1937 was greatly valued;

and that an expression of their sincere sympathy be conveyed to the members of the respective families."

The Scrutineers reported that the following had been duly elected as

Associate Members.

Donald Anderson Akins, B.E. (*New Zealand*).
George Russell Aldersley, B.Sc. (*Leeds*), Stud. Inst. C.E.
David Jack Anderson, B.Sc. (*Edin.*).
Charles Theodore Marshall Begg, B.Sc. (*Durham*).
John Henry Montagu Burton, B.A. (*Cantab.*), Stud. Inst. C.E.
Griffith Davies, B.Sc. (*Wales*).
Victor Denley.
William Downie.
John Harris Dyce.
Andrew Gamble, B.Sc. (*Belfast*), Stud. Inst. C.E.
Kenneth Frederick Geesin, Stud. Inst. C.E.
Mikhael Shlomo Gilutz, B.Sc. (Eng.) (*Lond.*).
James McPherson Gordon.
Charles Kenneth Haswell, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.

1

Desmond Edward Hennessey, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
Alfred Neville Hickling, B.A. (*Cantab.*).
Henry James Hopkins, B.E. (*W. Australia*), B.A. (*Oxon.*).
Michael Jacobson, B.Sc. (Eng.) (*Lond.*).
William Guy McGuire, B.Eng. (*Liverpool*).
Gordon Reinecke McKay, B.Eng., Ph.D. (*Liverpool*).
Samuel Maclean, B.Sc. (*Glas.*).
Arthur Henry Martin, B.A. (*Cantab.*).
Ian Ernest Mercer, B.Sc. (*Manchester*).
Gwyn Ewart Moore, B.Sc. (*Leeds*).
Arthur Lloyd Owen, Stud. Inst. C.E.
Thomas Frederick Parker, B.Sc. (Eng.) (*Lond.*).
Francis Pounder, Stud. Inst. C.E.
Robert Lawrence Raikes, B.Sc. (Eng.) (*Lond.*).
Percy Arthur Smith, Stud. Inst. C.E.
Richard John Soper, M.Eng. (*Sheffield*).
William Elwyn James Tanner.
Ivor Kirkland Taylor.
Norman Tetlow, B.Sc. (*Manchester*).
Francis Thomas, B.Sc. (Eng.) (*Lond.*).
Henry Daniel Watson.
Anthony Webb, B.Sc. (Eng.) (*Lond.*).
Stanley Joseph Slade Webber, B.Sc. (Eng.) (*Lond.*).
Arthur Leonard Wheeler, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
Stanley White, B.Sc. (*Durham*).
Arthur Lee Whitwam, B.A. (*Cantab.*).
Raymond Norman Williams, B.E. (*New Zealand*).

INFORMAL MEETING.

23 January, 1940.

SIR CLEMENT DANIEL MAGGS HINDLEY, K.C.I.E., M.A., President, in the Chair.

"Some Aspects of Engineering Civil Defence Works."

Introducer: THOMAS PEIRSON FRANK, M. Inst. C.E.

The Introducer referred first to the organization of Civil Defence Units, twelve of which were in existence to cover the entire country. The London Region, with which his remarks were concerned, was itself divided into nine groups, and covered the administrative County of London, the County of Middlesex, and parts of certain adjacent counties. The various groups were themselves divided into areas on a Local Government basis, thus including cities, boroughs, metropolitan boroughs, and urban districts. There was full co-ordination between the various areas in regard to repair and defence works, including all public services. He then went on to deal with the extent of damage likely, and observed that sewers having a cover of more than 8 feet might be safe from a 500-lb. general-purpose bomb.

Mr. Frank then mentioned flood-prevention works, and observed that there were two main contingencies to be guarded against: the first was the danger of flooding from the river; the second was that from burst water-mains or sewers. In regard to the first, a scheme had been prepared for rapidly repairing any breaches in the river banks, whilst flooding from burst water-mains or sewers would be dealt with by the existing pumping stations.

After describing some of the works necessary to provide additional fire-fighting services, he referred to the question of building partitions at about 200-yard intervals in pipe-subways, in order to break up long lengths of subways, thereby minimizing the risk of explosions from gas leaks. He briefly alluded to the protective measures carried out in a number of hospitals. He then showed a number of lantern-slides illustrating many of the points raised.

Mr. W. T. Halcrow, in opening the discussion, referred to the special work necessitated by the risk of flooding on the underground railways of London. Flooding might be brought about by either of two causes. The first was from damage to the tube lines where they passed under the river, and from damage to the Victoria Embankment, thus flooding the Metropolitan District Railway (and hence the tubes, by means of the connecting

passages at Charing Cross station). The second was from burst water-mains and sewers in the vicinity of stations.

The danger of long lengths of tunnel being flooded from the river was eliminated by the provision of flood-gates near both ends of the river-section of each tunnel, and on the District lines at selected points, whilst the connecting passages between the District and tube lines were provided with sector-type gates at their lower ends. The work of installing the gates was rendered more difficult by the fact that only about 3 hours was available for work each night, and that all electric cables in the tunnels at the sites of the gates had to be diverted through specially-constructed cable-headings. Mr. Halcrow showed a number of lantern-slides illustrating the construction and installation of the flood-gates, in explanation of his remarks.

He then referred briefly to the risk of flooding at stations from burst water-mains and sewers, and described the works carried out at certain stations to overcome the danger. The works consisted of water-tight doors in the various tunnels and escalator tunnels, and Mr. Halcrow concluded his remarks by showing some lantern-slides of typical water-tight doors.

Mr. V. A. M. Robertson gave further particulars of the works carried out by the London Passenger Transport Board, and stated that an immense amount of protective work had had to be done. Mr. W. T. Halcrow had, therefore, been asked to act as Consulting Engineer to the Board, and the successful conclusion of the major part of the work was a great tribute to him.

Mr. Harold Scott said that it had been very instructive to see on the screen many of the works that had been discussed months before, and, on behalf of the London Civil Defence Region, he wished to pay a tribute to the work of civil engineers. He also referred briefly to the co-operation between the various boroughs.

A vote of thanks to the Introducer, proposed by the President, was carried by acclamation.

ORDINARY MEETING.

20 February, 1940.

SIR CLEMENT DANIEL MAGGS HINDLEY, K.C.I.E., M.A., President, in the Chair.

The President, in referring to the death of Colonel R. E. B. Crompton, said that it had removed one of the most distinguished Members of The Institution and an engineer with a very remarkable record of achievement. The versatility of his genius, his unabated energy of mind during more than three-quarters of a century of active life, and his mastery of detail, had enabled Colonel Crompton to win distinction in many branches of electrical and mechanical engineering and to become one of the founders of the electrical industry. While his great services to the country and to engineering were receiving world-wide recognition, it was fitting that the members should recall with gratitude his work for their Institution. Colonel Crompton had been a Member of The Institution for 54 years and an active Member of Council for 32 years, and he had been elected an Honorary Member in 1934. Many Members of Council would recollect how Colonel Crompton had continued his active and enthusiastic support of all progress in The Institution's work, with an outspoken criticism of any retrograde step, maintaining his attendances at the meetings until after he had passed his ninetieth year.

It was therefore fitting that the following resolution of condolence should be passed:

> "That the members present at this meeting, on behalf of themselves and others, record the deep regret with which they have learned of the death of Colonel Rookes Evelyn Bell Crompton, C.B., F.R.S., who was elected a Member of The Institution in May 1886, and in March 1934 was elected an Honorary Member, in recognition of his long and valued services as a Member of Council from November 1902 until November 1934, and desire to express sincere sympathy with the members of his family in their bereavement."

The members assented to the resolution by standing in silence.

The President said that the Council recommended to the members present at the meeting the election as an Honorary Member of Mr. Maurice FitzGerald Wilson, the present senior Vice-President of The Institution.

He would remind the members that under By-law 11 the election of an Honorary Member was effected on the recommendation of the Council by vote of the members present at an Ordinary Meeting of The Institution. He felt that there would be a unanimous vote in favour of electing Mr. Wilson, a very distinguished colleague and a very great and close friend of many of the members, as an Honorary Member of The Institution.

The motion was carried by acclamation.

The Council reported that they had recently transferred to the class of

Members.

Walter Charles Andrews.
Albert Stevenson Fairn.
Archibald Milne Hamilton, B.E. (*New Zealand*).
Leonard Frank Jeffrey, B.Sc. (Eng.) (*Lond.*).
Christopher William Lacey.
Hugh Ross Lewis.
Edward Septimus George de la Motte, B.A. (*Cantab.*).
Harold Clayton Platts, M.C., B.Sc. (Eng.) (*Lond.*).
Charles William Seddon.
John Rognvald Shennan, M.C., B.Sc. (*Edin.*).
Howard Macoun Sherrard, M.C.E. (*Melbourne*).
Ernest Cecil Smith, Ph.D. (*Lond.*), M.Sc. (Eng.) (*Lond.*).
Frederick William Sully.
Feroze Muncherjee Surveyor, B.Sc. (*Glas.*).
William Victor Zinn, B.Sc. (Eng.) (*Lond.*).

And had admitted as

Students.

Robert Akerman.
William Edward Iredale Armstrong.
Jack Barnatt.
Geoffrey Hugh Elphinstone Baty.
Robert James Brierley.
Alan Brown.
John Steel Greenshields Brown.
William Gordon Cantlay.
Norman Casswell.
Arthur Dennis Clark.
Edward Gordon Clarke.
Douglas Clegg.
William Percival Coates.
Henry James Cobb.
Noel Wallace Collins, B.Sc. (*New Zealand*).
John Napier Cooper.
John Travers Cosgrove.
Donald Percy Creese.
George Richard Peto Cunningham.
Jagannath Behari Dalaya.
Douglas Henry Dale.
Alan Trevor Davies.
Edward Hughesdon Davies.
Donald Edward Dobson.
John Goslett Edwards, B.Sc. (*Durham*).
Philip John Farmer.
John Charles Flanagan.
Clifford James Frank.
Cyril Anthony Gloyn.
Robert Arthur Gordon, B.Sc. (Eng.) (*Lond.*).
Herbert James Gough-Cooper.
Thomas Moore Grant.
George Joseph Green.
George William Almond Gregory.
Ian Alexander Greig.
Harold Geoffrey Haden, B.Sc. (*Birmingham*).
Kenneth Mackintosh Hamilton.
George Hedley.
George Applegarth Hendry.
Edward Heney.
Norman Drummond Hetherington, B.Sc. (*Edin.*).
George Richard Hoffman.
Jack Horsfield.
Patrick Charles Hobart Houghton.
Mark Burnaby Hughes, B.A. (*Cantab.*).
John Waterloo Ind.
Ralph Alan Sefton Jenkins.
Cyril Alphonsus Bede Johnson.
Peter Frederick Johnson.
Peter Humphrey Jones.
Peter Turnley Jones.
John Charles King.
James Lamont, B.Sc. (*Manchester*).
Thomas Langham.
Edward Anthony Lees.

Douglas Clement Arthur List.
Graham Macfarlane.
Kenneth Kraige McKelvey.
Dugdale James McKillop.
Albert Desmond Hutchinson Martin, B.A.I. (*Dublin*).
John Anthony Martin.
Robert Marwick.
George James Belcher Mathews.
James Miller.
Peter Burgess Mitchell.
Geoffrey Colin Hay Morgan.
Wijeretnam Nadarajah.
Robert Cambridge Newell.
Edward Emery Peel.
Alexander Penman.
Thomas Arthur Noel Prescott.
Rex Percy Ramshaw.
Donald Edward Rayner.
William Montague Reading.
Isdale Robertson.
Alan Russell.
Victor Charles Schlienger.
Neil Seagar.
Frederick Andrew Sharman.
John Hay Shennan.
Norman Charles Slaughter.
Basil Standing.
Jack Sharland Staples.
Adrian Eric Gleadow Storrs.
Cyril William Straw.
Lawrence Albert Stredwick.
Ian Bruce Armstrong Turnbull.
Barry Trevor Turner.
Sommataya Sukhyanga.
John Robert Thornhill.
George Stewart Todd.
Ronald Smith Tulloch.
Gordon Richard Tucker.
Arthur Christopher Warman.
Kenneth Wyndham Warren, B.Sc. (*Witwatersrand*).
Leonard Stanley Wills.
Thomas Dunlop Wilson.
William John Youll.

The Scrutineers reported that the following had been duly elected as

Associate Members.

Kenneth Noel Ashton, Stud. Inst. C.E.
William Henry Newlin Calver, Stud. Inst. C.E.
Frederick Geoffrey Briggs Clayton, B.Sc. (*Leeds*), Stud. Inst. C.E.
William Gibbons Close, Stud. Inst. C.E.
Edward Arthur Dyer, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
Peter Matheson Gough, Stud. Inst. C.E.
John Jackson Hamilton, B.A. (*Cantab.*), Stud. Inst. C.E.
Richard Haviland Haviland, B.Sc. (*Witwatersrand*), Stud. Inst. C.E.
Jacques Herbert Hedgcock, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
Robert Harry James, Stud. Inst. C.E.
Kenneth Josey, Stud. Inst. C.E.
John Meldrum Leiper, Stud. Inst. C.E.
Robert James Rigg, Stud. Inst. C.E.
James Wyllie Shiell, B.Sc. (*Edin.*), Stud. Inst. C.E.
Harry Stiven, Stud. Inst. C.E.
Richard Lainsbury Triggs, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.

The following Paper was submitted for discussion, and, on the motion of the President, the thanks of The Institution were accorded to the Author.

Paper No. 5217.

"The Dragline Excavator." [1]

By William Barnes, M.I.Mech.E.

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[1] Correspondence on this Paper can be accepted until the 15th July, 1940, and will be published in the Institution Journal for October 1940.—Sec. Inst. C.E.

Part I.—THE DRAGLINE.

Introduction.

Shortly after the commencement of the twentieth century, a contractor, when digging a canal in Chicago, fitted a scraper bucket to a power derrick. That application of mechanical power to a modified form of horse-drawn scraper-pan or bucket was the commencement of the dragline excavator as it is known today[1]. The mechanism was so crude that it was impossible to visualize, at that time, what the idea would lead to. It is, in fact, only within recent years that engineers have realized some of the many uses and advantages of this type of single-bucket excavator. The purpose of this Paper is to enumerate and comment on these uses and advantages.

One of the great advantages of a dragline compared with its predecessor and competitor, the power shovel, is that it stands on the surface of the ground and digs below its own level. For that reason it was, at first, used mainly for under-water work, such as the cleaning out and widening of rivers, drains, and canals where a machine was unable to stand and work in the bottom. The dragline excavator is now, however, used extensively for jobs where the power shovel was, at one time, the accepted machine.

Compared with that of a power shovel the boom of a dragline is very much longer, and stability has to be considered more carefully. The working load, that is to say, the weight of the bucket and contents, should not exceed two-thirds of the tipping or overturning load, which takes into account the swing of the bucket beyond the boom-head radius, when dumping under certain conditions (see *Fig. 4*, facing p. 14).

Not only can the boom be easily varied in length, but the working radius can be altered by means of the boom-hoist gear, which should always be incorporated. A longer radius than the one recommended with the standard or maximum size of bucket can be used if the loading at the boom head is decreased by fitting a smaller bucket. When altering the length of the boom and the bucket-capacity the effects must, however, be very carefully considered, as otherwise the working speed and balance of the machine will be adversely affected. Counterweight is usually added to the rear of the machine to obtain the necessary stability. Although this takes care of the balance it adds weight to the machine, and thus necessitates either a decrease in the slewing speed or an increase in the power required for slewing. On the modern dragline, therefore, the machinery is placed behind the centre-post, where it acts as counterweight. This reduces the amount of ballast required and effects a saving in the weight of the machine.

The dragline is usually employed as an excavating unit, but sometimes, because of its long dumping reach, it is used both to dig and to transport the material. Good examples of this practice are the stripping of open-cast mines and the building of levees described in Part II of this Paper.

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[1] W. Barnes, "Excavating Machinery." Ernest Benn, Ltd., London, 1928.

The dragline is a useful and adaptable machine, and improved designs, resulting from field studies and experience, have added considerably, in recent years, to its many useful applications. For instance, not long ago the recommended maximum digging depth was only about one-half of the boom-head radius or length of boom. Now, however, digging depths equal to the boom-head radius are not at all unusual and depths 50 per cent. greater than the boom-head radius are being dealt with by fitting much longer booms and using buckets of improved design. Less than 10 years ago the longest boom-length available on a standard ½-cubic-yard machine was 28 feet, whereas 50-foot booms are now available on this size of machine, in conjunction, of course, with smaller and lighter buckets. At one time draglines were capable of digging only comparatively easy material; now, however, they are being used for really heavy material containing rock, and may even be used for excavating rock itself when it is sufficiently blasted and broken up, and when a machine large enough for the job is employed.

Largely because of the many improvements which have been introduced their use has been extended to: brickworks, both for stripping and for digging the clay; open-cast mineral mines and quarries; alluvial mineral deposits; and large public works of all descriptions at home and abroad. These and other applications are illustrated and dealt with in Part II of this Paper. Many recent successes have also been due to greatly improved designs of booms and buckets and to the use of modern materials and manufacturing methods.

Since the bucket is the "business end" of the machine it will be dealt with first.

The Bucket.

The digging efficiency of a dragline depends considerably upon the design of the bucket, and much thought and many field studies and tests have been made to determine such things as: (1) the best position of the bucket teeth and cutting lip relative to the digging pull; (2) the angle or set of teeth upon the cutting lip; (3) the cutting width of the bucket compared with its capacity and length; (4) the correct shape and curvature of the back; (5) the balance of the bucket to obtain clean dumping; (6) strength without unnecessary weight, to stand up against, not only the digging stresses, but possibly a certain amount of maltreatment when the bucket is lowered or "thrown" into the bottom of the cut under the combined control of the hoist and drag ropes.

Manufacturers, at one time, were content with one design or type of bucket, irrespective of the work the machine would be called upon to do, whereas, at the present time, four different types and weights of buckets are usually obtainable, as follows: (1) a standard bucket, for average digging; (2) a light bucket, for easy digging; (3) an "ultra-light" bucket, on small machines, for removing mud and soft materials from rivers and

drains; and (4) a strong heavy bucket for digging very heavy material, including rock or minerals. This last type is available only on medium-sized and large machines when the power available is sufficient for heavy duty.

The Standard Bucket.

Fig. 1 (facing p. 14) shows the latest type of standard dragline bucket which has been evolved from field experience in all kinds of digging; it incorporates many practical features which have greatly increased digging efficiency and reduced wear and maintenance costs. Modern all-welded construction has replaced the riveting previously employed, and this, together with carefully-studied scientific design incorporating strength where it is most needed and reducing weight in other places, has produced a much stronger bucket than those previously used, although weighing between 25 and 30 per cent. less.

Flat plates, although heavy, offer very little resistance to bending or twisting stresses, so that in this new bucket the body plate has been reduced in thickness and then strengthened by welding stiffeners where the greatest stresses and wear take place. These welded stiffeners are clearly seen around the top inside and outside edges of the bucket, and along the sides near the bottom. In addition, square-section rubbing pieces are welded on to the underside of the bucket to protect the body plate as it is dragged along the material which is being excavated. Another great advantage of the all-welded bucket is the absence of rivet heads inside the bucket, which results in a smoother and cleaner surface for both digging and dumping.

Another weak feature of the old dragline bucket was the tendency for the sides to pull in at the front, where the drag chains are attached, due to the resultant inward pull of the chains. This weakness has been eliminated by fitting an all-welded box-section arch and a cast manganese-steel lip which greatly stiffen the front of the bucket. The manganese-steel front has sockets into which are fitted renewable and reversible alloy-steel or high-carbon-steel teeth.

Wear on the pins and shackles which attach the drag and hoist chains to the bucket and rope connexions is severe, so that large circular links of alloy or manganese steel are fitted on the new buckets, to distribute the pressure and reduce the wear.

Floating bushes on the bale lug pins, special quick-change renewable steel links, and other details are all the result of the previously-mentioned field studies.

The Light Bucket.

The light bucket is similar in construction to the standard bucket, except that the body plate is a little thinner and an alloy-steel plate lip

replaces the one of manganese steel. Less stiffening is employed and the bucket is about 20 per cent. lighter in weight than the standard bucket.

The "Ultra-Light" Bucket.

The "ultra-light" bucket has very little stiffening by comparison with the standard and light buckets and is only suitable for cleaning out mud and light materials from drains and rivers. It is about 40 per cent. lighter in weight than the standard bucket, and will not stand much punishment.

The Heavy Bucket.

The heavy bucket is similar in general design to the standard bucket, but is heavier and stronger. More steel castings are employed in its construction and it is about 25 per cent. heavier than the standard bucket.

There are several advantages in being able to choose a bucket to suit the nature of the digging. For example, if a standard bucket of 1-cubic-yard capacity and weighing 2,250 lb. is used for digging stiff moist clay weighing 3,000 lb. per cubic yard, the gross load is 5,250 lb. This can be assumed to be the safe working load. Supposing, however, that the same machine is required to dig loamy soil or easily-excavated dry clay weighing 2,200 lb. per cubic yard, then a 1¼-cubic-yard light-type bucket weighing 2,270 lb. can be used, as the 1¼ cubic yard of material will weigh only 2,750 lb.; the gross load will therefore be 5,020 lb., compared with the gross load of 5,200 lb. when using the 1-cubic-yard standard bucket in heavy clay. As the loamy soil is easy to dig the 1¼-cubic-yard bucket can safely be used. It will be seen, therefore, that, by changing the bucket at a comparatively small cost, 25 per cent. greater output is obtainable.

Users are recognizing that the lighter the bucket, consistent with its ability to dig, the greater the efficiency or pay load, and, if a larger output is required or can be dealt with, the increase in output quickly pays for a new bucket. One user consistently uses the lightest bucket obtainable, saying that the larger output he obtains more than pays for the greater maintenance costs of the light bucket.

Sometimes digging and dumping radii are of greater importance than output, especially for cleaning out rivers or drains, and it may be possible to increase the length of boom by fitting a lighter bucket. An example is a dragline with a working radius of 40 feet using a 1-cubic-yard standard bucket weighing 2,200 lb. in material weighing, say, 2,500 lb. per cubic yard, giving a gross load of 4,700 lb. On most drain- and river-clearance jobs a light-type bucket will readily handle the material, so that if a 1-cubic-yard light-type bucket weighing 1,900 lb. is substituted for the 1-cubic-yard standard bucket it is quite practicable to increase the radius to 45 feet, which may be a considerable advantage.

A wide range of dragline buckets is available, capacities ranging from

$\frac{1}{4}$ cubic yard upon a machine weighing 7 tons to 20 cubic yards upon a machine weighing 1,200 tons.

The Boom.

Mention has already been made of the great advance which has taken place in boom-lengths during recent years, even upon machines of the same bucket-capacity.

Formerly, all booms upon machines up to about $1\frac{1}{2}$-cubic-yard bucket-capacity were constructed of mild-steel channels, and, upon larger machines, of mild-steel angles with riveted lattice bracings.

Recently, however, riveting has been replaced by welding, and this, together with improved designs and the use of modern materials, has reduced the weights of the booms. In addition, the boom fittings, especially the boom-head connexions and pulleys, have been reduced in weight. Everything, in fact, has been done to obtain minimum weight with adequate strength to obtain the big working ranges which are useful features of modern draglines. Better balancing of machines has also helped the adoption of longer booms.

The modern dragline boom is usually built up of a number of sections so that its length can easily be altered to suit different working conditions. For instance, the standard length of boom upon a certain machine is 60 feet, and it is constructed of two sections; it carries a bucket of $2\frac{1}{2}$ cubic yards capacity. The same boom can, however, be increased in length to 70, 80, or 90 feet by adding sections 10 feet long, bolted between the two main sections, to take buckets of 2-, $1\frac{1}{2}$-, and $1\frac{1}{4}$-cubic-yard capacities, respectively. This is frequently very useful, as sometimes, on different parts of the same job, greater or smaller digging ranges are required and therefore the booms can be altered to suit. This sometimes obviates the necessity of installing another machine.

Working Ranges.

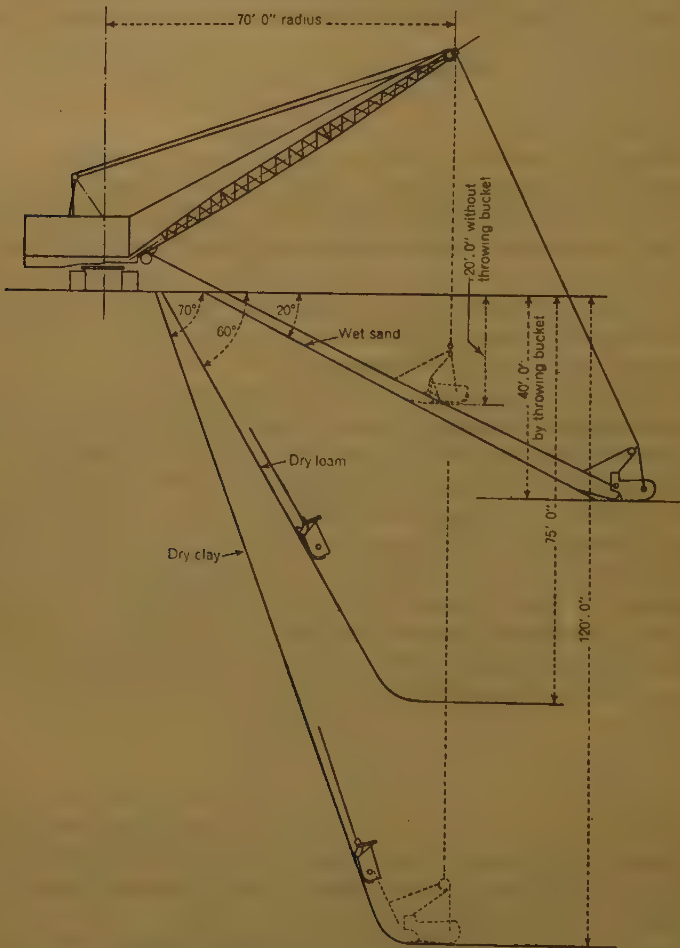
Digging Depth.

The practical digging depths of dragline excavators have increased enormously within recent years, and, in certain cases, have more than doubled, chiefly because of the use of longer booms and more efficient buckets.

Given a definite boom-length and a modern bucket, the maximum digging depth is now dependent almost entirely upon the nature of the material, including its hardness or the resistance it offers to the bucket teeth and its natural angle of repose, as shown diagrammatically in *Fig. 2* (p. 14). In this diagram three representative materials are shown: wet running-sand with a natural angle of repose of 20 degrees; dry loam or similar material, very easy to dig, with an angle of 60 degrees; and dry clay standing up to an angle of 70 degrees.

It is apparent that wet running sand is a difficult material to deal with because as fast as the material is dug from the toe and the face it "flows" to a flat angle of repose which greatly limits the digging depth. The longer the boom the greater, of course, will be the possible digging

Fig. 2.



Digging Depths and Working Ranges.

depth. In the diagram the bucket in running sand is shown thrown well out beyond the boom-head radius, which is good practice for certain jobs, not only in shallow digging, but in faces with a normal depth. A study of *Fig. 2* will make it clear how the maximum digging depth depends upon the boom-head radius and the angle of the working face.

It is only possible to excavate the dry clay shown at the steep angle if

Fig. 1.

THE STANDARD BUCKET.

Fig. 3.

"THROWING" THE BUCKET FOR DIGGING.

Fig. 4.

"THROWING" THE BUCKET FOR DUMPING.

Fig. 5.

THE "WALKING" DRAGLINE.

the material is not too hard to be dug with the bucket resting on the face at that angle, because, of course, the pressure upon the teeth due to the weight of the bucket is, comparatively speaking, very small. The fact, however, that digging to about this depth is practicable is proven by a dragline, with 70-foot boom and 1½-cubic-yard bucket, which is digging clay to a depth of over 100 feet near Bletchley.

To take an extreme example, if the material stood vertically, the bucket would also hang almost vertical on or near the face, and in that position there would be practically no pressure or weight upon the teeth to penetrate the material.

Digging Radius.

Fig. 3 (facing p. 14), and *Figs. 6* and *7* (facing p. 22), show that the bucket can be thrown out well beyond the boom-head to increase the digging radius, thus enabling a wider cut to be taken. This is especially useful for cleaning out rivers and drains. The length of throw beyond the boom-head, which can easily be 30 per cent. greater than the boom-head radius under favourable conditions, depends, to some extent, upon the depth of the excavation or surface of the water below the working-level of the machine. The maximum and easiest throw is obtainable when the material or surface of the water is well below the working-level of the machine, so that a normal pendulum swing from the boom-head is obtainable; otherwise the length of the pendulum swing must be reduced, by shortening the hoist rope, so that the bucket will clear the material or water at the lowest point of its swing. In deep faces, it is difficult to co-ordinate the "paying-out" of the drag and hoist ropes to avoid dropping the bucket heavily in the bottom. Under these conditions, to prevent possible damage to the bucket, it is advisable to lower the bucket at the boom-head radius and to make no attempt to throw it. It should be borne in mind that throwing the bucket increases the cycle time, so that if maximum output is required it is better to use a larger machine with a longer boom.

Dumping Radius.

For dumping into wagons the dumping radius is equal to the boom-head radius as the bucket is suspended vertically from the boom-head by the hoist rope. For dumping to spoil or back into water the bucket can, however, be swung out several feet beyond the boom-head. This practice is useful sometimes to increase, slightly, the dumping radius (*Fig. 4*, facing p. 14), or to spread material (*Fig. 16*, facing p. 31).

Dumping Height.

The bucket can be dumped at any height from a point immediately under the boom-head to a reasonable distance below the working-level of the machine.

Digging Powers and Speeds.

The digging power should bear a definite relation to the capacity of the bucket and the speed should be as high as is consistent with control of the bucket during the progress of the cut. If the speed is too high the bucket cannot be filled efficiently. Field experience under many different conditions has determined the best digging powers and speeds.

Modern practice indicates that, in average material under average digging conditions, the drag pull, which is approximately the digging effort upon the bucket-teeth, should be between 16,000 and 18,000 lb. per cubic yard of bucket-capacity for small machines, approximately 14,000 lb. per cubic yard for 3-cubic-yard machines, and approximately 12,000 lb. per cubic yard for 12-cubic-yard machines, with digging speeds between 140 and 180 feet per minute.

To avoid loss of time in dumping, the hoisting and slewing motions should be carried out simultaneously so that the correct dumping height coincides with the end of the swing. This means that for high dumping, either on to a bank or into a hopper, the bucket has to be hoisted higher during the slewing period. Since slewing speeds are faster on modern machines the hoisting speed has been increased from about 110 feet per minute to 150–200 feet per minute. More powerful engines or electric motors are also fitted to obtain the greater digging, slewing, and hoisting speeds.

Variable Digging Powers and Speeds.

Another valuable feature of the modern dragline is the provision of interchangeable drum laggings of different diameters, by means of which the digging pulls and speeds and also the hoisting speeds can be altered to suit different digging conditions. Thus, for hard digging, a small drum lagging is bolted to a permanent drum spider mounted on the drum-shaft to obtain a powerful cutting effort. This lagging is in halves to facilitate changing. Inversely, for easy digging a larger drum lagging can be fitted to increase the digging speed and yet retain sufficient digging power to deal with the easier material.

For very deep digging, large-diameter drum laggings are available to avoid, as far as possible, coiling the rope in more than one lap or layer. This increases, of course, the digging and hoisting speeds and proportionately decreases the digging and hoisting pulls, but this, generally speaking, is not a disadvantage as, because of the deep face, a thinner cut, requiring less cutting effort, is taken to fill the bucket over the longer distance resulting from the deep face. A smaller bucket is also usually employed, because of the longer boom which is necessary to deal with the deep cut. The reduced drag and hoist pulls are therefore sufficient for the smaller bucket and a comparatively fast operating cycle is maintained, even in the deep face.

Motive Power.

Internal-combustion engines or electric motors are used, almost exclusively, for the motive power. They have superseded steam engines because of the difficulties and expense, with steam machines, of obtaining coal and suitable water, maintaining an adequate working-pressure throughout the day, raising steam in the morning, washing out the boiler at regular intervals, and the expense of a fireman. In practice, also, it is found that larger average outputs are obtainable from excavators driven by electric motors or by internal-combustion engines than from steam machines. Field records show that the net working time, with steam as the motive power, averages from 65 to 75 per cent. of the gross working hours compared with from 85 to 90 per cent. with internal-combustion engines and from 90 to 95 per cent. with electric motors.

For use in permanent situations such as pits and quarries, electricity is usually favoured, but contractors and users who have to move the machines about from place to place naturally prefer diesel or petrol engines as the motive power.

The recognized practice for draglines with buckets up to 2 or 2½ cubic yards capacity is to fit a continuously-running internal-combustion engine, or electric motor, and to drive all the various motions through friction clutches. When the clutch-operated type of machine was first introduced a considerable amount of prejudice had to be overcome in spite of the fact that, even when separate steam or electric-power units were employed for the various motions, clutches and brakes were necessary for controlling the digging and hoisting motions and the only additional clutch required for the clutch-driven dragline was for the slewing motion. It must be admitted, of course, that when clutch-driven machines were first introduced the clutches were anything but perfect. Upon modern machines, however, the clutches are very efficient both for easy operation and long life, with consequently low maintenance costs, which probably accounts largely for the fact that at least 95 per cent. of the excavators now constructed are clutch-operated. The remainder consists chiefly of large machines fitted with Ward-Leonard electric control where, if clutches were used, they would be so large and heavy that they would be difficult to operate. This applies, however, only to the slewing and travel clutches, as, even upon the largest draglines, the digging and hoisting motions are necessarily controlled through power-operated clutches.

Large draglines of what is known as the "walking" type (which are described later in this Paper) are also obtainable fitted with diesel engines as the motive power, for situations where electric power is not available. Some of these machines weigh more than 600 tons and are fitted with diesel engines of 600 horsepower. Upon these machines the diesel engines, in addition to providing direct power to the digging and hoisting motions, drive generators with Ward-Leonard control which supply current to the slewing motors.

In order to obtain the greater digging power and operating speeds characteristic of modern machines, larger power units per cubic yard of bucket-capacity are now employed, so that the horsepower now ranges from 70 to 90 per cubic yard of bucket-capacity, compared with about 50 to 60 on early models.

Caterpillar Tracks.

Caterpillar tracks, self-laying tracks, or crawlers, as they are variously called, are among the most useful and revolutionary features ever introduced upon excavators. They add from 25 to 35 per cent. to the cost of an excavator, compared with rail-wheels, but in spite of this, and because of the increased mobility and great saving in time and labour resulting from their use, they have replaced entirely the rail and road wheels previously used.

The usual bearing- or ground-pressure on caterpillar tracks varies from 10 to 15 lb. per square inch, which is suitable for travelling on ordinary ground without the use of timbers or wood mats. For soft ground, however, specially long and specially wide tracks are available which, depending upon the size and make of machine, reduce the bearing-pressure to 7–10 lb. per square inch.

For power shovels, long tracks are not advisable, as they do not allow sufficient working clearance around the machine for the shovel bucket, or dipper, as it is frequently called to distinguish it from the bucket of a dragline. This disadvantage does not, however, apply to a dragline and frequently it is very desirable to use the specially long and wide tracks. Sometimes the ground, as, for instance, soft marshy ground alongside a river, is too soft even for oversize caterpillar tracks and for these conditions timber mats or rafts should be used. These mats, because of the large area upon which they stand, result in a low bearing-pressure of the order of 2–5 lb. per square inch, depending upon the area of the mats and the size of the machine.

The foregoing remarks refer to draglines up to about 80 tons in weight. For very large draglines whose weight runs into hundreds of tons, as high in fact as 1,200 tons, the matter of bearing-pressures becomes a more difficult problem, owing to the difficulty and expense of fitting caterpillar tracks proportionate to the weight of the machine. The bearing-pressure upon the tracks of the largest machines runs as high as 40–45 lb. per square inch. This can be more than halved by the use of timber mats under the tracks, but for some conditions this is still high, although it can be reduced to a more workable figure by specially large mats. This, however, entails loss of time and extra cost of labour in laying them down.

The "Walking" Dragline.

The problem of weight and bearing-pressure on very large draglines has been solved by the use of what is known as the "walking traction" device shown in *Fig. 5* (facing p. 15). Machines fitted with this device were at first used chiefly on the soft ground alongside the Mississippi River for building levees, but they are finding increasing favour for other classes of dragline work, and hundreds are in use in America. Six of them have recently been put to use in the Nigerian tin fields and five in the English ironstone mines. Two, weighing over 600 tons each, were supplied to steelworks in Germany in 1939.

When the "walking" dragline is in operation the superstructure can revolve on a big circular base which "sits" on the ground and takes the place of the more usual caterpillar tracks. This base ranges from about 18 to 36 feet in diameter (according to the size of the machine) and results in the low bearing-pressure of 5–9 lb. per square inch.

Large shoes or rafts, lifted well clear of the ground when the machine is digging, are fitted to the machine, one on each side of the revolving frame. When it is required to move the machine to a new location the "walking" machinery is put into motion and the two shoes are simultaneously lowered on to the ground until the weight of the machine is transferred from the base to the shoes. As the motion continues the whole machine, exclusive of the shoes of course, is first lifted and tilted and then moved forward a distance of 6 or 7 feet, the rear portion of the machine, meanwhile, trailing on the ground. The tilting motion of the machine ingeniously breaks the suction under the base on soft ground. A very important and useful feature of the "walking" device is that the machine can step off or "walk" in any direction by simply slewing the superstructure into the direction in which it is required to move.

Part II.—APPLICATIONS.

Drainage and Irrigation Works.

Draglines are extensively used for digging drainage ditches and irrigation canals, for widening, deepening or cleaning out existing ones, and for building or "throwing up" banks and levees.

Many sizes and designs are available for widths of from 2 to 500 feet or more, an excellent proof of the wide range of sizes obtainable.

The biggest irrigation job ever undertaken was the Sukkur barrage in India, officially known as the Lloyd Barrage and Canals Construction Scheme, which involved the excavation of approximately 210,000,000 cubic yards of material in digging over 6,000 miles of canals with

bed widths ranging from 6 to 350 feet. Forty-six draglines were used, weighing from 20 to 300 tons each, and fitted with buckets of capacities ranging from ⅞ cubic yard to 10 cubic yards. Work was commenced in 1924 and was completed in 1932. The largest machines, nine in number, weighing 300 tons each, were supplied with booms ranging from 100 to 145 feet in length with buckets of capacities ranging from 10 to 6 cubic yards. They were all steam machines, but owing to the cost and difficulty of supplying them with coal and obtaining suitable water for the boilers there is little doubt that, if a similar job were undertaken in these days, diesel-electric or all-electric machines would be employed, where the machines could be centralized to take power from suitable power-stations. Rail-wheel mountings were used upon the machines as caterpillar mountings were not, at that time, fitted to machines of this size and the walking dragline was practically unknown.

After 3 or 4 years' work with the big steam machines, and because of the difficulties with coal- and water-supply, two medium-size diesel-electric draglines were ordered (electrically operated with 180-horsepower diesel engines driving 120-kilowatt generators, mounted upon the machine). The boom-lengths were: 85 feet with 4½-, 100 feet with 3½-, and 115 feet with 2½-cubic-yard buckets. They were mounted on caterpillar tracks.

Five medium-size steam draglines were also employed, two with 80-foot booms and 4-cubic-yard buckets, and three with 80-foot booms and 3-cubic-yard buckets.

For the smaller canals thirty "straight-diesel" draglines were employed with buckets ranging in size from ⅞- to 1½-cubic-yard capacity.

Table I is a list of approximate working costs of the various machines, taken over periods ranging from 6 to 12 months. The costs per cubic yard are operating costs, and include labour, fuel, spares, and repairs, but do not include interest and depreciation.

TABLE I.

	Fuel.	Cost of fuel per cubic yard: pence.	Cost per cubic yard: pence.
Big steam draglines	Coal	1·2	3·5
Medium-size steam draglines . .	Coal	1·0	2·8
Diesel-electric draglines	Diesel-oil	0·3	1·9
Small diesel draglines	Diesel-oil	0·14	1·4

Upon another irrigation scheme in India, the Cauvery–Metur Scheme in the Presidency of Madras, diesel-electric draglines were used but were mounted on caterpillar tracks; the cost worked out at approximately 1·2*d.* per cubic yard. It should be noted that the costs given are for the unusually difficult conditions encountered in India, and are chiefly of value for

comparing the costs of different sizes and types of machines under similar conditions.

In continuation of the above comparisons it is interesting to note the working costs (Table II) of the draglines used on the Salonika Plain Reclamation Scheme[1].

TABLE II.

	Cost of fuel and lubricants per cubic yard: cents.	Cost per cubic yard: cents.
Steam 1¾-cubic-yard dragline (on pontoon) . .	2·28	5·00
,, 2½- ,, ,, ,, ...	1·99	4·88
Diesel-electric 6-cubic-yard dragline	0·85	2·97
,, ,, 3½–5- ,, ,, (on pontoon)	0·78	3·25
Diesel 2-cubic-yard dragline	0·45	2·29
,, 1½- ,, ,, ,, ...	0·57	2·94
,, ¾- ,, ,, ,, ...	0·36	1·71
Petrol ¾- ,, ,, ,, ...	1·45	3·15

Here again the chief value of the figures is the comparison of the different types and sizes of the machines, all draglines, but in both instances the relatively low costs of the diesel machines are shown.

DRAINAGE IN GREAT BRITAIN.

Hundreds of draglines are being used upon the many drainage schemes which are being carried out by the numerous drainage and catchment boards in Great Britain.

The work varies considerably and includes the cutting of new drains, the cleaning out of existing channels and rivers from a few feet wide up to 100 feet or more wide, and the construction and strengthening of embankments.

Fig. 6 (facing p. 22) shows a ½-cubic-yard dragline widening a small fen drain with a bottom width of 30 feet, and strikingly illustrates the possibilities of even a small machine for work of this description. The "throw" of the bucket, referred to in connexion with *Fig. 3* in Part I of the Paper, is clearly shown. As already mentioned, it is better to employ a machine with a longer boom, to avoid loss of time in throwing the bucket, but on many drainage schemes a machine of average size has to be used to suit the different jobs which have to be dealt with. The cost of the job illustrated was about 9*d.* per cubic yard, including trimming the banks and all capital charges and depreciation. The cost was greater than it otherwise would have been owing to the bad travelling conditions.

[1] B. J. Huntsman, "The Salonika Plain Reclamation Works." Journal Inst. C.E., vol. 5 (1936–37), p. 243 (March, 1937).

Upon another job where the travelling conditions were better, the cost of the excavation, including depreciation, etc., was approximately 4*d.* per cubic yard plus 2*d.* for trimming and sowing the banks.

The costs for cleaning out and trimming the banks of another drain about 12 feet wide at the bottom and 12 feet deep was 3·8*d.* per cubic yard. This cost included 20 per cent. interest and depreciation and the wages of three men, an operator and two labourers.

The cost depends, of course, on the size of the drain and the amount of material which has to be taken out, but a small drain 2½–3 feet wide at the bottom and 8–9 feet wide at the top can usually be cleaned out for about 12*s.* 6*d.* to 15*s.* 0*d.* per chain, excluding capital charges, but including two men for trimming the banks. Table III gives detailed working costs, taken over a period of 12 months, for a ½-cubic-yard dragline, fitted with a petrol–paraffin engine, cleaning out a wide drain.

TABLE III.

Item.	Cost per cubic yard: pence.
Paraffin	0·53
Petrol	0·12
Engine-oil	0·14
Machinery-oil	0·03
Repairs and maintenance	0·28
Miscellaneous	0·05
Labour on, and around, the machine	3·8
Total	4·95

The neat trimming of the banks of a fen drain excavated by dragline are worth remarking upon. This finish is obtained by men using long-handled spades, the material being broken down into the bottom of the drain and taken out by the dragline.

Fig. 7 shows a ¾-cubic-yard dragline raising and strengthening embankments alongside a drain and, incidentally, cleaning out and improving the channel. It illustrates the method of cutting a trench by hand on the opposite bank, in advance of the machine, to assist the operator to cut a straight bank at the correct slope. As Mr. F. H. Tomes pointed out[1], if the trench side is made to the required angle, the operator, by dropping the bucket into the trench, can correctly cut the slope on the far side.

WORKING ON MARSHY GROUND.

The problem of using a dragline on soft ground is referred to under the heading "Caterpillar Tracks" in Part I of this Paper.

[1] "Fen Drainage." Transactions Inst. W.E., vol. xlii (1937), p. 198.

Fig. 6.

WIDENING A FEN DRAIN.

Fig. 7.

DIGGING WITH THE AID OF A GUIDE TRENCH.

5217.

Fig. 8.

CLEANING A DRAIN WITHOUT DISTURBING THE BANK.

Fig. 10.

A DRAGLINE MOUNTED ON A PONTOON.

The digging of a drainage channel through the jungle in Malaya is an example of the difficult conditions under which some machines are called upon to work. Long timbers are used to support the machine on the very soft ground. These timbers have to be man-handled separately, but with an ample supply of cheap native labour available this is feasible. Usually, however, it is cheaper and quicker to use mats which consist of several timbers securely bolted together and fitted with eye-bolts so that the drag-line, by means of sling-chains and hooks attached to the eye-bolts, can pick up the mats from the front and relay them at the back of the caterpillars or vice versa.

Ditches on the Zuider Zee Reclamation Scheme.

A large number of $\frac{1}{2}$-cubic-yard draglines were employed for cutting drainage ditches, 3–4 feet wide and 4–5 feet deep, upon the big £20,000,000 Zuider Zee Reclamation Scheme in Holland. The material was easily-excavated clay or silt. The location and top-width of the ditches were indicated by two men cutting small trenches about a foot wide and a foot deep with one side made to the correct slope of the finished ditch. The final trimming of the slope was made by two men, one on each bank, who worked close up to the dragline to enable the operator to pick up, with the bucket, the material broken down into the bottom of the ditch.

Outputs of 5,000–5,500 cubic yards, in a working week of 55 hours, were obtained, with a normal average output over long periods of 60–70 cubic yards per hour, this output taking into account all stoppages.

Canal Excavation: Working Costs.

Table IV (p. 24) gives details of costs for the excavation of a canal from sandy clay, using a dragline with a $1\frac{1}{4}$-cubic-yard bucket, sidecasting, and working two shifts per day (96 hours per week.) The average output was 137 cubic yards per hour (13,152 cubic yards per week).

Removing Silt from Existing Drains.

The banks of the drain shown in *Fig. 8* were in excellent condition, and it was required to remove from $1\frac{1}{2}$ to 2 feet of silt from the bed of the drain without digging into them. The usual position of the fairlead pulleys at the foot of the boom made it difficult for the bucket teeth to clear the bank unless the dragline was placed nearer to the edge of the drain than was desirable. A pulley for the drag rope was therefore fitted at a point about 8 feet up the boom. This, as shown in *Fig. 8*, enabled the operator to lift the bucket out of the bottom, clear of the bank.

A similar difficulty arose on another job when it was required to clean out a small irrigation canal where the berm was not wide enough for

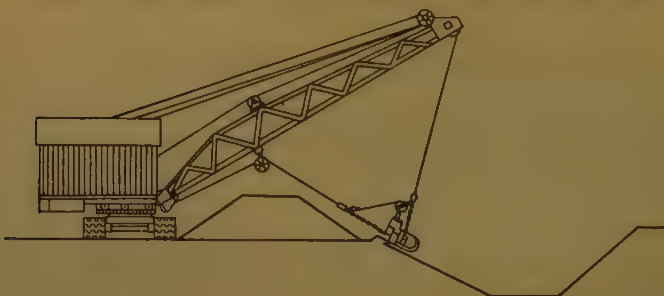
TABLE IV.

Item.	Cost per week: £ s. d.	Unit costs.
Labour:		
Two operators at 2*s.* per hour, each	9 12 0	
Two boys at 9*d.* per hour, each	3 12 0	
Fuel:		
Diesel-oil: 319 gallons at 6*d.* per gallon	7 19 6	0·15*d.* per cubic yard (41 cubic yards per gallon).
Lubrication, etc.:		
Engine oil: 16½ gallons at 3*s.* per gallon	2 9 6	0·05*d.* per cubic yard.
Machine oil: 2 gallons at 2*s.* 6*d.* per gallon	0 5 0	
Grease: 33 lb. at 3½*d.* per lb.	0 9 0	
Cotton waste	0 0 10	
Repairs and maintenance (excluding ropes)	5 10 0	0·1*d.* per cubic yard.
Ropes: derricking rope every 4 months; hoist rope every 2 months; drag rope every 4 weeks	3 9 0	
Total	£33 6 10	

Total cost per cubic yard (excluding capital charges): 0·61*d.*

the dragline. The problem was solved in a similar manner by constructing a special boom with a pulley up the boom so that the drag rope cleared the top of the bank as shown in *Fig. 9.* A carrier at the back was specially

Fig. 9.



fitted to carry spares and supplies when the machine was travelling from one job to another.

DRAGLINES MOUNTED ON PONTOONS OR BARGES.

Sometimes, when it is required to clean out a watercourse, the channel may be too wide for the dragline to reach the material from the bank or banks. The problem may be solved by mounting the dragline on a

pontoon and discharging the excavated material directly on to the bank or into wagons, or into barges if the machine is unable to reach the bank.

Fig. 10 (facing p. 23) shows a large diesel-electric dragline working upon the Salonika Plain Reclamation Scheme, referred to in the working costs on p. 21. To counteract the digging reaction and to hold the dragline up to its work the pontoon must be fitted either with shore anchors, operated from warping winches attached to the corners of the pontoon, as shown in *Fig. 10*, or with "spuds." The "spuds" may be either hand- or power-operated, depending upon their weight and size.

When a shallow river has to be cleaned out or deepened and the machine cannot work from the bank or banks, it is possible sometimes, if the bed of the river is sufficiently firm, to travel the machine in the river and to dump the excavated material upon the banks or into lorries.

A "Walking" Dragline on the Albert Canal, Belgium.

Fig. 11 (facing p. 26) shows a "walking" dragline at work on the Briegden–Gellick section of the Albert Canal, which runs from Antwerp to Liège. The Albert Canal was commenced in 1930 and was to have been opened in 1939. It takes barges up to 2,000 tons capacity, cost about £100,000,000, and involved the excavation of about 100,000,000 cubic yards of material. The canal is approximately 78 miles long (the old one was 96·3 miles long) and now runs entirely through Belgian territory. The dragline, fitted with a 6-cubic-yard bucket on a boom 135 feet long, is shown working in a deep wide cutting near Lanaeken.

The upper portion of the material in this cutting consisted of clay and the lower portion of gravel. The clay and gravel were excavated separately by the dragline. The former was used to construct the banks on the lower levels of the canal and the latter as an aggregate for approximately 80,000 cubic yards of concrete necessary for lining the sides of the canal. It is a useful illustration of the ability of a dragline to excavate, separately, layers or benches of different kinds of material. The machine worked, almost continuously, two or three shifts (18–24 hours per day), for 4–5 years and excavated about 5,500,000 cubic yards at the average rate of approximately 100,000 cubic yards per month. The machine, powered by a 280-horsepower diesel engine, weighed about 300 tons. The average output was approximately 240 cubic yards per hour, and the diesel-oil consumption was approximately 6·5 gallons per hour (about 37 cubic yards per gallon).

Levee Construction on the Mississippi River.

The biggest exacavation jobs in the world, as far as draglines are concerned, are the flood-control schemes in the Mississippi basin. Commenced over 200 years ago, by hand labour, they have developed in recent

years to highly mechanized schemes. Floods alongside this famous river were recorded by De Soto, the Spanish explorer, as far back as 1543.

The first levee was constructed in 1717, and the Governor of New Orleans boasted that it was a mile long and 18 feet wide. Local construction, financed by the inhabitants of this district, developed from that date until, by 1812, embankments had been built on both banks for a distance of 340 miles. Federal operations date from 1820 and from then have proceeded with increasing momentum. The Mississippi River Commission was created in 1879 and, in 1881, $1,000,000 was granted for this work. In 1927 the greatest flood on record occurred and in 1928 $325,000,000 was authorized by Congress for levee construction. In 1935 $272,000,000 was added to the amount still unexpended under the 1928 Act, and a further grant of $40,000,000 was made in 1937–38.

Since 1928 about 650,000,000 cubic yards of material have been placed in the levees over an aggregate length of about 2,000 miles.

Commencing about 1912, draglines, mostly of the "walking" type, have been chiefly used for this work because of their very low bearing-pressure on the ground and their ability to sidestep and zigzag so as to obtain the necessary digging width and to dump the wide levees which have been, and are still being, constructed. Approximately one hundred excavators of this type have been, or are being, used upon the various schemes.

Because of the heavy cost of coal for steam machines and the difficulty of obtaining suitable water for the boilers, diesel engines, even upon the largest size, are used almost exclusively.

Generally speaking the digging is very easy and, as dumping radius is of great importance, light steel or aluminium-alloy booms are largely used in conjunction with light-weight buckets.

The contract price ranges from a minimum of 8 cents to a maximum of 24 cents per cubic yard.

The levees are built up of material excavated from borrow pits adjacent to, and parallel to, the levees. Several methods are employed to build these big levees, and the rehandling of the material is reduced as far as possible. Two of the methods are shown in *Figs. 12* and *13* (p. 27).

In *Figs. 12* the finished levee is 219 feet across the base and 22 feet high; the necessary material is obtained from a borrow pit 243 feet wide and 18 feet deep, tapering off to practically zero near the berm. Two draglines are employed, a large one with a 160-foot boom and a 6-cubic-yard bucket for digging the material, and a smaller one, on the dump side, for taking off the peaks and spreading the material as nearly as possible to the required section. The final levelling is carried out by hand labour. The three-peaked section on the levee side is obtained by zigzagging the big machine as shown in the plan.

In *Fig. 13*, showing a levee 171 feet 6 inches across the base, one drag-line only is employed and it is travelled in a series of steps or stages over

Fig. 11.

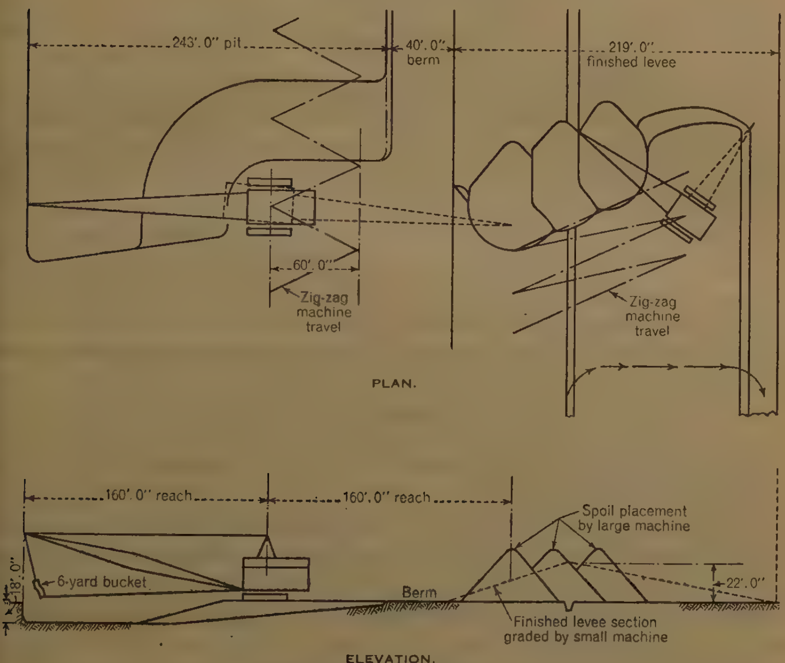
EXCAVATING STRATIFIED MATERIAL: A "WALKING" DRAGLINE ON THE ALBERT CANAL, BELGIUM.

Fig. 14.

THE "ALL-AMERICAN" CANAL.

a distance of 125 feet. It is only necessary to spread some of the material on the far side of the levee, shown by the dimensions 26 feet 6 inches, which is beyond the normal dumping reach of the machine.

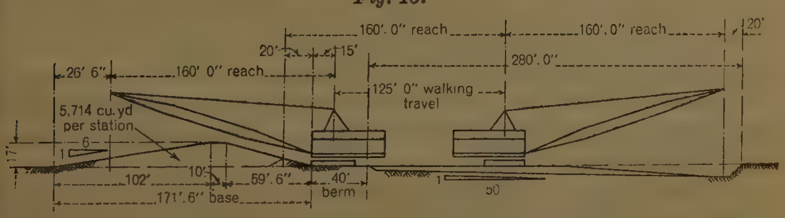
Figs. 12.



BUILDING A LEVEE.

Table V (p. 28) gives representative outputs from "walking" draglines with varying boom-lengths and bucket-capacities working on the Mississippi levees.

Fig. 13.



It will be noticed that in the smaller machines with shorter boom-lengths the average output per cubic yard of bucket-capacity is greater, because of the shorter boom-lengths and the consequent shorter distance that the material is transported or dumped.

TABLE V.

Length of boom: feet.	Capacity of bucket: cubic yards.	Average hourly output (three 8-hour shifts per day, 7 days per week): cubic yards.	Hourly average output per cubic yard of bucket-capacity: cubic yards.	Remarks.
150	8	350	43	Average monthly output: 245,000 cubic yards.
150	7	280	40	Average monthly output: 195,000 cubic yards.
150	5½	240	43	Maximum output in a month: 285,000 cubic yards (an average of 400 cubic yards per hour).
120	6	390	65	—
120	6	450	75	—

THE "ALL-AMERICAN" CANAL.

Fig. 14 (facing p. 27) is an aerial view of a portion of the "All-American" canal [1] in California, which involved the excavation of about 14,000,000 cubic yards of material. The main canal is 80 miles long with a branch canal 130 miles long. The east section of the canal is 160 feet wide at the bottom and 22 feet deep, with slopes of 1 in 2. The deepest cut through the "sandhill area" was 115 feet deep. The total cost was about £9,000,000 and the scheme will irrigate about 1,000,000 acres of land by means of water from the Colorado River.

The job was placed out to contractors, who tendered approximately 6*d.* per cubic yard for the dirt, mainly sand and silt, and from 2*s.* to 5*s.* per cubic yard for a quantity of rock which was encountered.

Seven diesel-driven "walking" draglines were employed, with buckets of 12, 6, and 3 cubic yards capacity, together with a number of small draglines with 2-cubic-yard buckets.

One of the 12-cubic-yard draglines, working 24 hours per day, excavated the enormous quantity of 5,501,000 cubic yards in 12 months.

The portion of the canal shown was excavated in two cuts, the material being dumped on each side to form the banks. The method of working is clearly shown in *Fig. 14*.

In some portions of the canal cemented gravel was encountered and excavation proved very difficult. Blasting was at first resorted to, but it entailed too much delay, and a cast-steel rooter, weighing over 10 tons, was substituted for the dragline bucket.

[1] "The All-American Canal." *The Engineer*, vol. clxvii (1939), p. 696 (9 June) and p. 728 (16 June).

The rooter was dragged through the compact gravel and when sufficient material had been loosened it was removed and the digging was continued with a 12-cubic-yard bucket.

Sand and Gravel.

The excavation of sand and gravel, especially when the deposit is waterlogged, is one of the best known applications of a dragline. In most pits the sand and gravel is dumped by the dragline into tip wagons, and then transported to the washing, crushing, and screening plant. Occasionally, when the material is waterlogged and sufficiently loose, a gravel pump mounted on a pontoon is used to excavate the aggregate and also to convey it, by means of a pipe-line, to the plant. Usually, however, the material is too compact to excavate with a gravel pump and a dragline is then used to dig the material. Sometimes the dragline works near to the gravel pump and the material is dumped from the bucket of the dragline into the water near to the suction end of the pump. This method is only efficient with a short pipe-line between the gravel pump and the plant; it is now more usual to locate the gravel pump near to the plant and to transport the material in tip wagons or dumpers from the dragline. One of the chief purposes of using a gravel pump in this manner is to elevate the aggregate to the plant, together with a supply of water, and to give it a preliminary wash in the process. Another method is for the dragline to dump the material into barges, for transport to the plant, where it is unloaded by a grabbing crane and dumped into an elevated hopper of the plant.

Where only a comparatively small output of gravel is required per day, transportable screening, or washing and screening, plants are available, travelling on road or rail wheels.

In some pits, when it is not too deep, the dragline first removes the overburden and dumps it into the bottom of the worked-out portion of the pit, and then digs the sand and gravel in an exactly similar manner to the method described in connexion with the ironstone working (p. 31). Where water is present in the pit this method is more difficult, and it can only be used if the dragline boom is sufficiently long to dump the material well clear of the toe of the gravel.

Some pits contain beds or pockets of clay or other material mixed with the sand or gravel. These can be removed separately by means of a dragline. An example of this is a pit where there is 10 feet of gravel, then 15 feet of clay, whilst below that there is another 15 feet of gravel. The dragline first digs the top 15 feet and puts it into wagons; then the bed of clay is removed and dumped back into the worked-out portion of the pit; finally, the lower 15 feet of gravel is excavated.

Excavating Beach Gravel.

An unusual method of digging beach gravel by means of a ½-cubic-yard dragline has been devised. At high tide, barges are sailed as near to the shore as possible and then anchored. As the tide goes out the barges settle down on to the beach. As soon as the tide recedes sufficiently the dragline travels across the beach to a working position alongside one of the barges. The dragline then digs the gravel and loads it into the barges. Two or three barges are loaded in this manner until the incoming tide forces the dragline to retire up the beach to safety. It also refloats the stranded barges, which sail away with their cargo.

The tide serves a useful purpose in that it fills up the holes left by the removal of the gravel and provides a supply for the next tide. The barges have a capacity of from 100 to 200 tons and a dragline has loaded as much as 500 tons in 4 hours.

Digging and Separating Stratified Materials.

Draglines are being increasingly used to dig, and to remove separately, stratified materials. An interesting example occurs in a gypsum quarry (*Fig. 15*, where the gypsum is interstratified with hard marl. The total depth of the working face is approximately 52 feet. The upper portion of the material, about 34 feet deep, is removed by an electrically-operated shovel, which dumps the material (gypsum and marl) into a screening plant combined with a conveyor, the latter depositing the separated marl on to the dump or open side of the quarry.

The lower 18 feet of material consists of five bands of gypsum from 6 to 12 inches thick, interstratified with beds of marl from 1 foot to 4 feet 6 inches thick. This lower face is excavated by an electrically-operated dragline having a working radius of 70 feet and fitted with an 80-foot boom and 1¾-cubic-yard bucket.

The method of working is to excavate the different strata separately. The marl, which is in the proportion of 4 of marl to 1 of gypsum, is dumped across the quarry on to the ground which has been worked out. As each bed of gypsum is exposed it is, if necessary, drilled and blasted. It is then excavated by the dragline and dumped 40 feet high on to the surface of the quarry, where it is cleaned and sorted by hand labour.

The dragline, it is interesting to note, replaced three small excavators which were used to dig the layers of marl and gypsum separately. It also dispensed with an overhead cableway used for transporting some of the clay on to the dump, and has effected a saving of 70 per cent. in working costs.

It was a practical solution to a difficult problem, and it is fascinating to watch the ease with which the operator can gather detached pieces of

Fig. 15.

SEPARATING GYPSUM AND CLAY IN A QUARRY AT NEWARK.

5217.

Fig. 16.

STRIPPING IRONSTONE AND RESTORING THE GROUND FOR CULTIVATION.

gypsum into the bucket and leave the clay behind to be dealt with by another cut.

Stripping Ironstone.

In some open-cast ironstone mines, the ground, after the ironstone has been removed, has to be, or is, restored for cultivation. In some instances this is one of the conditions of the lease, but in others the companies concerned are doing it on their own initiative. Restoration is not quite so easy as it appears to be, as it means not only levelling the ground after the ironstone has been removed, but replacing the sub-soil and top soil or loam in their correct relative positions. This necessitates removing first the upper 6–9 inches of top soil and loam, then excavating the sub-soil and dumping it on the ground from which the ironstone has been removed, and finally spreading the top soil over the surface of the sub-soil; if the comparatively small percentage of top soil and loam were mixed with the sub-soil the ground would be unsuitable for agricultural purposes.

In all instances when a power shovel is used to remove the cover, and the ground has to be restored, the loam is taken off and replaced on the sub-soil by hand labour. This costs from £80 to £100 or more per acre, which is far more than the ground is worth for agricultural purposes, and the land is therefore left in "hill and dale" formation, either derelict or planted with trees. A few years ago, therefore, the Stanton Ironworks Company, Limited, decided to instal a dragline in one of their shallow mines, not only to remove the cover but to do the resoiling. The experiment proved successful and, as a result, the use of draglines for this purpose has increased considerably. It is interesting to know that land restored in this manner produces better crops than it did before it was disturbed.

Costs vary widely according to the depth of cover and similar conditions, but in some quarries stripping, resoiling, and levelling are done with a dragline at a total cost of 2*d.* to 3*d.* per cubic yard, excluding amortization charges. It is difficult to take out of the total cost the amount for restoring the land, but it will probably amount to as little as £15 or £20 per acre, which certainly makes it a desirable and practicable proposition.

The method of working is as follows. The sub-soil, from which the loam has been removed by the dragline on the previous cut, is excavated and dumped over on to the ground from which the ironstone has been taken out. The material is roughly spread by allowing the bucket to swing out, pendulum fashion, during the dumping operation. It is then roughly levelled by lowering the bucket, teeth downwards, on to the dump, and by drawing it towards the machine, using it like a rake. A further levelling is done by two men. The loam, at the side, is then excavated and dumped on to the surface of the sub-soil, the final levelling being done by the same two men. *Fig. 16* shows how accurately

level the machine can remove the material, and it is surprising how efficiently the ground is levelled and restored on the dump side.

This method of working is another useful example of how material can be separated efficiently, especially as, in some instances, the dragline is digging the ironstone as well as stripping and restoring the cover.

In some ironstone quarries the surface of the ironstone is very undulating, in the form of pronounced steps. This, however, offers no real difficulty to the dragline, which is used to strip off the cover, and the top of the ironstone is left comparative clean. No other power excavator could cope with these conditions so successfully.

Open-cast Mining: Stripping and Rehandling Deep Cover.

The overburden in the ironstone quarry shown in *Fig. 17* varies considerably in depth, and in some parts the big stripping shovel seen on the right has not sufficient reach to dispose of the whole of the material. To avoid using a larger machine for the maximum depth only, a dragline has been installed on the top of the dump to rehandle the excess material and deposit it further back from the open cut, and so make room for more material from the shovel. The newly-dumped material is comparatively loose and soft and the dragline is therefore worked upon large timber mats.

Coal-Stripping in the United States.

Many shallow coal deposits in the United States which cannot be mined by underground methods, because of the thinness of the coal seams and bad roof conditions, are being mined successfully by stripping. Over 20,000,000 tons of coal are being obtained annually by stripping thin seams of coal from 2 to 6 feet thick.

Until a few years ago long-boom shovels were used almost exclusively for removing the cover, but the dragline has invaded this field and many are now employed for this purpose. In some instances the dragline has replaced the shovel (*Fig. 18*, facing p. 33), but in other mines where the cover is over 50 feet deep, the dragline, because the largest shovels, weighing from 1,000 to 1,200 tons, have not sufficient reach to deal with this depth of overburden, is supplementing the shovel by dealing with the upper portion of the cover, as shown in *Figs. 19* (p. 33).

In one pit, where the overburden is about 55 feet thick and consists of clay, limestone, and shale, a 15-cubic-yard shovel is digging the lower 30 feet, whilst a 12-cubic-yard dragline is removing the upper 25 feet. The output is approximately 5,600 cubic yards per shift of 8 hours from the shovel and 4,000 cubic yards from the dragline. The shovel is advanced 10 feet at each move-up and the dragline approximately 30 feet.

In another pit where the overburden, consisting of clay and hard shale, is about 40 feet thick, a "walking" dragline is used, equipped with a

Fig. 17.

OPEN-CAST MINING: STRIPPING AND REHANDLING DEEP COVER.

5217.

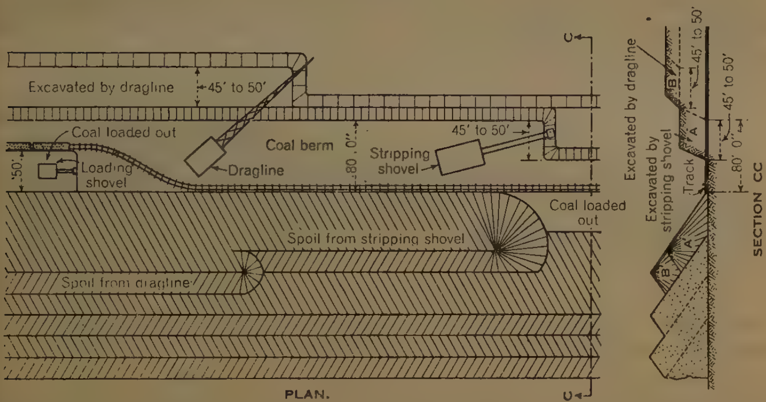
Fig. 18.

COAL STRIPPING BY DRAGLINE.

105-foot boom and a 5-cubic-yard bucket. The machine is operated in three 8-hour shifts per day, and the output averages 121,200 cubic yards per month, or approximately 235 cubic yards per hour. The shale, which lies immediately above the coal seam, is shaken up by blasting, for which purpose horizontal 3-inch holes are drilled 45 feet into the bank at about 15 inches above the seam of coal.

Fig. 18 shows a typical open-cast coal mine. In this mine the cover is from 32 to 54 feet thick and consists of from 12 to 20 feet of loamy

Figs. 19.



soil above 20–34 feet of shale. The coal seam is about 2 feet 6 inches thick. In order to obtain a more efficient dumping radius and a firmer and more level surface for the dragline, it stands upon the shale, so that the 12–20 feet of soil is excavated from above the working-level of the dragline and the 20–34 feet of shale from below. About 80 per cent. of the shale is blasted, using horizontal holes.

Gold-mining with Draglines.

The placer dredge is recognized as being the cheapest method of dealing with large deposits of placer gravel. The drawbacks to the method are the comparatively high cost of the equipment and the depth of the deposit, which must usually be from 12 to 15 feet to provide the necessary flotation. Within recent years a new system has been adopted, which has successfully bridged the gap between the high cost of hand labour on small deposits and the high cost of equipment such as is used on big areas of proved deposits. The system consists of a dragline working in conjunction with a barge or scow carrying a hopper to take the material dumped from the dragline bucket, a trommel, a pump, riffle sluices, a stacker or belt conveyor, and a power-plant. The unit is in fact a small placer dredge without the excavating equipment, which is replaced by a

dragline. In addition to being less costly than a placer dredge, the "doodlebug", as it is called in America, only requires a flotation depth of 30 inches or less. Another advantage is the great flexibility and ease of transport for dealing with irregular and small deposits. This method of working with dragline and "doodlebug" has proved so popular in California that scores of plants of this description are being used. It is said that more gold has been extracted by their use during the last 8 years than was obtained during the great Californian gold rush.

The plants vary considerably in size, from small installations working with draglines of about ½ cubic yard bucket-capacity, used for prospecting and dealing with isolated deposits, up to large plants capable of dealing with big outputs and working in conjunction with draglines of 4 or 5 cubic yards bucket-capacity.

Where water is comparatively scarce, the machinery, instead of being mounted on a barge, is carried on a caterpillar-mounted framing for use on dry land, and the water required for the washing operation is returned to a sump and circulated. The combined digging and washing costs range from about 2½*d*. to 6*d*. per cubic yard.

Provided that the washing and screening plant is effective, the dragline need lose little, if any, time because of the fact that it is dumping into a large hopper placed at a convenient dumping point; large outputs are thus obtainable. On one plant, for which information is available, an average of 180 cubic yards per hour was dealt with using a dragline with 1½ cubic yard bucket-capacity. On another, with a dragline of 4 cubic yards bucket-capacity, an average of 330 cubic yards per hour was dealt with.

At first the "doodlebugs" were more or less improvised, but several firms are now producing them in a range of sizes.

Digging Clay for Brickmaking.

Many brick companies are successfully using draglines for both stripping and digging the clay. *Fig. 20* shows two electrically-operated machines in one of the London Brick Company's yards at Peterborough. The machine in the foreground is digging the clay or shale and dumping it into a large storage hopper, which is fitted at the bottom with power-operated sliding doors through which the wagons are filled as required. The machine in the distance is removing the cover and dumping it on to the ground from which the clay has been taken out. It is essential when excavating clay from a clay pit to mix the clay, preferably by taking an even cut throughout the full depth of the working face; this can be done effectively by means of a dragline.

It is interesting to see in *Fig. 20* how it is possible to cut a steep face on the exposed side. This is very desirable, as the clay does not then absorb so much moisture and is therefore much better for the brick-

Fig. 20.

DIGGING CLAY AT PETERBOROUGH.

Fig. 21.

OPENING A NEW CLAY PIT NEAR BEDFORD.

Fig. 22.

A DRAGLINE HANDLING ROCK.

making process used for this particular clay, or "knotts", as the Fletton or Oxford clay is called locally.

Opening up a New Clay Pit.

Fig. 21 shows a dragline with a 70-foot boom and a 2-cubic-yard bucket opening up a new clay pit by removing the cover to expose the clay. The cover was approximately 16 feet thick and it was opened up 112 feet wide in two cuts. The material from the first cut, 58 feet wide, was dumped on to the surface of the cutting. It was then rehandled by the dragline and placed further away from the cutting to make room for the material taken out by the second cut, which is seen in progress. The output when digging from the solid on the first and second cuts was approximately 8,000 cubic yards per week, whilst the rehandling was effected at the rate of 5,500 cubic yards per week. After the pit was opened up the dragline was placed in the bottom of the cut to dig the clay.

It is interesting to note the elevated forward position of the operator's cabin; this enables the operator to see the full length of a deep face and makes it easier for him to control the thickness of cut in order to mix the clay.

Excavation of Trenches.

The drag-shovel is used mostly for excavating trenches, but sometimes the dragline is used with satisfactory results. A dragline will cut a trench with steep sides when the material stands up well without much timbering. The bucket is sometimes fitted with side teeth to make it easier to cut the sides. To leave the sides vertical the operator usually holds the bucket up to its work on the sides of the trench by means of the swing motion, but, if the trench is wide enough, it is better to cut two trenches the width of the bucket in a line with the two sides so as to avoid an open side, and then to take out the centre portion by subsequent cuts.

If a very wide cutting is required the dragline can be travelled backwards and forwards across the end of the cutting, at right angles to the centre-line of the trench, instead of travelling along the centre-line.

Railway Cuttings.

Draglines are being increasingly used, in preference to shovels, for excavating railway cuttings when there is not too much rock in the material. The advantages are: (1) the excavator and wagons are kept out of the bottom; (2) it is easier to instal and maintain the tracks for the dump wagons if these are required to take the material away; alternatively, if the material can be deposited on the surface alongside the cutting, the dragline can dump direct. A dragline can also cut the slopes or batters more efficiently and more cheaply than a shovel.

Cut-and-Cover Work.

The Colorado River aqueduct, which cost over £40,000,000, is a concrete conduit, 16 feet in diameter and lifts water 1,617 feet above the Colorado River and carries it over 400 miles of hills and deserts through tunnels, conduits, and canals to South California. The work took 15 years to complete and gave employment to 35,000 men, the maximum at any one time being 10,000.

The large trench necessary to receive the conduit was excavated by draglines, and the excavated material was deposited on both sides. After the conduit was placed in position the draglines were used to backfill the material to a minimum depth of 3 feet over the crown. Diesel or electric draglines, of both the caterpillar and "walking" types, were used, with buckets ranging from 2 to 6 cubic yards capacity. The open canals were also excavated with draglines with buckets of $1\frac{3}{4}$ and 2 cubic yards capacity, although on two of the contracts a 5-cubic-yard electric dragline was used.

Rehandling Material.

Although draglines are primarily employed for digging material from below the level of the machine, they are occasionally used for dealing with material above the working-level (see *Figs. 18* and *19*), and also for rehandling material where greater dumping room is required (see *Fig. 17*).

They are also sometimes used for spreading dumped material. The method of working is to commence digging from the top of the dump, working down to the bottom by successive horizontal cuts. It is possible, by careful driving, to avoid dragging the material into the caterpillar framing and creating a windrow.

Rock Excavation.

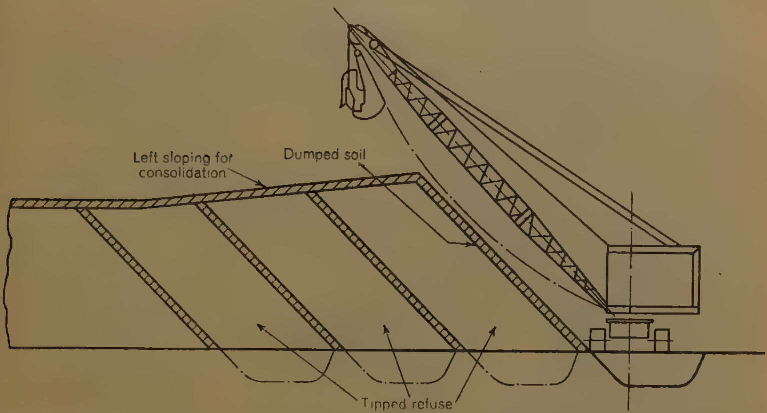
It is quite possible to excavate rock by means of a dragline if the rock is sufficiently loose in the face, or, failing that, if it is well loosened and broken up by blasting. *Fig. 22* (facing p. 35) shows a dragline engaged on work of this description using a heavy "rock-type" bucket. The machine is shown digging one of the canals upon the large Vaal-Hartz irrigation scheme in South Africa, which has cost over £4,000,000. A large dam to form a lake 90 miles long with a maximum width of 12 miles has been constructed at the junction of the Vaal and Hartz Rivers to supply water along a distance of 350 miles from the dam. Many draglines were employed upon this scheme and quite a lot of rock was encountered similar to that shown in *Fig. 22*.

Covering Refuse Dumps.

Refuse dumps or tips, if uncovered, are an undoubted eyesore as well as being unsanitary; the practice of covering them with soil is therefore an excellent one. It is difficult and costly to carry out the work by hand labour, but the work is being done quickly and cheaply by means of draglines.

The usual method of working is to cut a trench alongside the toe of the tip as shown in *Fig. 23* and to dump the excavated material on to the top and sides, the final spreading and levelling being carried out by means of hand labour. The advantages of this method are that useful loam or

Fig. 23.



soil, instead of being covered up, is turned to a useful purpose and the trench from which it has been taken is available for refuse. The covering process closely follows the tipping so that as little as possible of the refuse is left uncovered, even for a short period.

The "Dragveyor."

The "dragveyor" is a new idea for conveying material from a dragline so as to obtain larger outputs under suitable working conditions, which include a comparatively shallow cut in easily-excavated dry material. The dragline shown in *Fig. 24* (facing p. 38) is fitted with an 8-cubic-yard crescent-shaped slack-line-cableway bottomless bucket in place of the usual 3-cubic-yard dragline bucket, and the material, instead of being picked up and swung round for discharging, is dragged up an incline into a hopper communicating with a conveyor fitted with a 60-inch belt. The discharging end of the conveyor is elevated sufficiently to load into large 16-cubic-yard dump trucks which are run into position under the end of

the conveyor. The hopper has a considerable storage capacity to avoid the necessity of synchronizing the digging and discharging operations. Loading of the trucks is controlled by an operator on the conveyor so that the conveyor is only operated when a truck is in position.

Some time is taken up by manœuvring the dump trucks into position under the end of the conveyor, but the outfit shown in *Fig. 24* is loading at the rate of 550 cubic yards per hour, loose measurement, which is approximately double the output which would be obtainable from the dragline when fitted with a standard 3-cubic-yard bucket under similar working conditions.

The World's Largest Dragline.

In conclusion, it may be interesting to give a few particulars of the largest dragline so far constructed. The "walking" type is shown in *Fig. 25* (facing p. 39), but the same size of machine is also supplied with caterpillar mounting. The following is a brief specification :—

Length of boom : feet . . .	200	225	250
Capacity of bucket : cubic yards	15	12	10
Maximum dumping radius : feet	214	240	265

Working weight	Approximately 1,000 tons.
Electric drive	Ward-Leonard control.
Digging motors	500 brake horsepower.
Diameter of base on "walker"	45 feet.
Bearing area	1,590 square feet.
Bearing area with caterpillar mounting	384 square feet.
Approximate time for 1 cycle of operations	65–75 seconds.
Output, depending on material and working conditions	350–650 cubic yards per hour with 15-cubic-yard bucket.
Current consumption	0·5–0·75 kilowatt-hour per cubic yard.

Fig. 25 clearly shows the "walking" device, the operator's cabin, the large superstructure, the long boom, and the widespread feet.

Acknowledgements.

The Author wishes to thank the following excavator manufacturers for their assistance in supplying information or photographs, or both :— Bucyrus-Erie Company ; Koehring Company ; Link Belt Company ; Menck & Hambrock ; Orenstein & Koppel ; Page Engineering Company ; Priestman Brothers, Limited ; Ransomes & Rapier, Limited ; Ruston-Bucyrus, Limited ;

Fig. 24.

THE " DRAGVEYOR."

Fig. 25.

THE WORLD'S LARGEST DRAGLINE.

Thos. Smith & Sons, Limited; and the Thew Shovel Company. He wishes to thank also the numerous excavator users whose machines are illustrated and who have kindly supplied working information and costs.

The Paper is accompanied by five sheets of drawings and fifty-two photographs, from some of which the Figures in the text and the seven half-tone page-plates have been prepared.

Discussion.

The Author, in introducing his Paper, showed a number of lantern-slides, followed by a cinematograph-film of the "walking" dragline.

Mr. J. R. Davidson observed that the Paper clearly showed that the dragline excavator provided engineers with a convenient and economical means of excavating material of all kinds, and that it possessed, for a great variety of purposes, marked advantages over other types of excavators. As the Author pointed out, one of the main reasons why the dragline had those advantages was that it stood for its work on the original surface of the ground, above the material to be excavated, and thus avoided having to work from the bottom of the excavation. That feature gave the additional advantage that, if the material being dealt with were taken away as spoil in wagons, the wagons themselves moved on undisturbed ground. Another valuable feature was the ability of the dragline, within the limits imposed by the radius of the boom, to transport the material over a considerably greater distance than most other forms of excavator.

Fig. 2 (p. 14) was very interesting. It clearly showed the influence which the class of material being dealt with had on the maximum depth to which excavation could be carried out, but he would suggest to the Author that some information as to the depths for maximum economy of working would be very useful. He would take the case of a standard dragline with a bucket of 1-cubic-yard capacity, working in dry loam or ballast and delivering into wagons, which meant that the tipping-point was, say, 10 feet above the level on which the machine stood. In such a case as that, what was the most economical depth for working, and within what range on either side of that figure would the most economical price apply?

He agreed with the Author as to the great importance of suiting the

type of bucket to the particular job to be dealt with, and also the necessity of eliminating superfluous weight from the boom and its fittings—in fact, from all the moving parts. At the same time care had to be taken, as he was sure the Author would agree. Some of the welded lattice booms seen on draglines appeared to be extremely light. They were subject to considerable strains and shocks during working, and the tendency to increase the motive power used and the speed of working also emphasized the need for ample strength without undue weight in the boom.

The Paper contained some valuable Tables with regard to working costs, but he would suggest that it would be more convenient if the units of cost could be the same; in Table I (p. 20) the costs were given in pence and in Table II (p. 21) they were given in cents. He realized, of course, that it was not fair to compare the costs in the two Tables, because the work might have been done under totally different conditions.

The illustrations in the Paper showed clearly the ability of the machine to work in ground where there were stratified layers of different materials, and the way in which an expert operator could separate the different classes of material that had to be dealt with was extraordinary. The dragline had another very valuable feature, namely, the ability to make a nearly vertical cut. The Author referred to the advantage of that in getting clay for brick-making, in that a mixture of the different layers was obtained; Mr. Davidson might add that where embankments were being formed from stratified alluvial deposits it was a great advantage at times to be able to get a cut the whole depth, so as to obtain a more or less uniform mixture, instead of getting layers of different classes of material, which would tend to produce a bank which was not so strong as a thorough mixture would give.

He was interested in the question of the maximum size of dragline. The Author said in his Paper, in the section dealing with buckets (pp. 10 *et seq.*), that the largest machine had a 20-cubic-yard bucket, but at the end of the Paper, where details were given of the world's largest dragline, a 15-cubic-yard bucket appeared to be the largest. He believed that the first statement was correct, and that the capacity of the largest bucket was 20 cubic yards.

He wished to refer very briefly to one development of the dragline which was not mentioned in the Paper. It might be held that strictly it was not a dragline, but he thought it was, as it was a single-bucket machine operated with hoisting rope and drag ropes. He referred to the tower-scraper, where the bucket, instead of being suspended from the end of a boom, was suspended from a traveller running on an overhead cable. He had four machines of that type working at present, with which it was possible to excavate over a width up to 800 feet. The cable was slung between two towers, the one at the end where the material was being tipped being, of course, very much higher than the anchor-tower. The two towers travelled on parallel lines of rails and straddled both the

area to be excavated and the area on which the material was being tipped. The largest machines which were working on the two jobs with which he was connected were forming embankments over 50 feet in height, and were electrically operated. Those machines had buckets of 3½ cubic yards capacity, and it took about 2 minutes to complete the cycle of operatons. In order to employ the tower-scraper it was clearly necessary to have the work confined within a comparatively small area, as the machines could not be moved a great distance. The amount of material to be moved within that area had to be sufficient to make it worth while to go to the expense of erecting such plant. For certain purposes, however, he believed that that type of machine offered a field for considerable development.

Mr. Oscar Borer rather joined issue with the Author on the point of the dragline having originated in the United States, because in the office of Messrs. Priestman Brothers there was a sketch made on an envelope by Mr. Philip Priestman and Mr. Crowther when they were dealing with the problems of the Ouse Drainage Board in 1922–1924, and the sketch showed a crane mounted on wheels with something indicating a dragline attachment, with which the scraper scoop was to be used from the base of the jib instead of being lifted from the jib-head, the whole machine being drawn by a tractor. There was a development of that in one of the old machines of the Ouse Drainage Board which had passed to the ownership of the Great Ouse Catchment Board; it had been built in 1926, and had wheels in the front portion and caterpillar tracks behind. That machine was still working. Many of the catchment boards had pressed dragline manufacturers in Great Britain to keep on developing their machines, and had insisted that the machines should be as light as possible. In the last 10 years the ½-cubic-yard machine had been developed from having a 28-foot jib to having a 50-foot jib, and for ordinary commercial purposes that was the limit, but the catchment boards had insisted that 60-foot jibs should be available.

He was very interested to see in the Paper a reference to the fact that the weight of the bucket and its load should be about two-thirds of the tipping or overturning load. That was a point which catchment boards continually bore in mind, and every time they found they had a little more stability in hand he was afraid that they were guilty of insisting upon the jib on the next machine being increased in length.

He had been trying for some time to get a further development in the way of draglines, and certain of the dragline manufacturers in Great Britain were specializing in meeting the demands of the catchment and drainage boards. It should be noted that the machine had to bring its load within range of the lifting power at the base of the jib, and so the question arose as to why the load needed to be lifted at all. His board had therefore set to work to see whether they could develop such a machine. Their first development had been to use an ordinary ¼-cubic-yard machine, which had a standard jib of 32 feet, and to have that jib increased in length

to 40 feet. Then they had decided to use a scraper scoop, so that instead of lifting ¼ cubic yard they would drag ½ cubic yard. That form of development was, however, suitable only for shallow-river conditions.

Mr. Borer then showed three lantern-slides illustrating the machine which his board had developed for doing a deferred maintenance job, where there was no necessity to cut very deeply but where it was mainly silt that had to be pulled out. The machine did that, and also pulled the material to the side. In so far as the scraper scoop was used, it could only be pulled on to the bank in front of the machine. It became necessary for the machine itself to stand some 10 feet back from the bank. That setting back of the machine was offset by the bigger outreach obtained from the 40-foot jib. The scraper scoop was slung right across to the opposite bank and the material dragged back across the river and deposited in front of the machine. The advantage was that ½ cubic yard was handled each time instead of ¼ cubic yard. A further development took place in connexion with the high banks along the Tidal River. There a normal 12-cubic-foot machine with a 40-foot jib was all that could be used on account of the weight of the machine itself on the banks, which consisted only of silt. The catchment boards generally had increased the 40-foot jib to 45 feet, but as it was necessary on that job to secure an outreach of from 70 to 75 feet, a special jib 55 feet in length was constructed, making full use of electrically-welded designs. On the low tide a 1-cubic-yard scraper scoop was used which hauled the material by the side of the bank out of range of the high tide; then when the tide rose the scraper scoop was taken off and the bucket put back, and the machine continued to lift the material and to put it on the top of the bank. He did not think that it would be possible to stretch things much further than that, because the position had been reached when it became almost impossible to control the swinging of the machine, due to the great length of jib, except at very low speeds.

The Author referred in his Paper to the use of the dragline afloat. The experience of his board with a dragline afloat had not been a very happy one. Generally speaking, in the operation of a dragline the scoop was loaded by being pulled into the working face, and when it was loaded it was tilted up and lifted. In the case of dredging along a river, however, the machine was dredging from deeper water into shallower water, and therefore there was nothing for the drag scoop to pull against. His board had tried to use the machine afloat, but it was quite useless in the case of soft material, and they had to go back to using it as a grab. In one case on the river Trent it had been used, but there a fairly firm gravel was being handled, and the gravel held until the drag scoop managed to cut through it, but anything softer than that was simply pushed under the pontoon. Therefore when a dragline was used afloat it turned itself into an ordinary grab dredger, and the cost was doubled.

His experience had been that, whereas a diesel-operated machine

might be used for dragline work, it was extremely doubtful whether it was an economical machine to use for grabbing. For grabbing work, where there was really hard work to do, his experience was that the steam machine could not be beaten. It was true that three men had to be in attendance instead of two, but that was of no consequence, because when there was a pontoon afloat there had to be a deck-hand to look after it, and he might just as well assist in keeping up steam. With good steam coal no difficulty was experienced in keeping the steam dredgers working well. He was surprised to see the statement in the Paper that the net working time, with steam as the motive power, averaged only from 65 to 75 per cent. of the gross working hours. His board had had no difficulty whatever in keeping steam machines working continuously, and when hard digging was in progress steam machines had every advantage over diesel machines: when it was necessary to use the full purchasing power that could possibly be obtained for closing the grabs, a steam-driven machine stood up to the work better than a diesel-driven one.

The Author referred to the increase in working radius; the increase of the boom radius had helped his board to solve one of their problems. The old practice in fen drainage was to work by hand and to deposit half the spoil on one bank and half on the other; it had been regarded from time immemorial as the right of drainage boards to do that, and they paid no compensation. The dragline had originally introduced a complication, in that all the material had to be deposited on one side, and the owner of the land on that side naturally objected. The increase of boom radius made it possible for a skilled driver to deposit part of the spoil on the other side of the stream or ditch, although it was only now and again that an operator was sufficiently skilled to swing his machine out and to dump half the material on the opposite side.

Mr. H. A. Henry observed that the Author and the previous speakers in the discussion had rightly viewed the subject of the dragline in its broadest aspects, but to a British contractor's engineer one of the principal points of interest about the dragline was the way in which it had revolutionized excavation work in Great Britain. Previous to 1920 or thereabouts, mechanical excavation work had been more or less limited to the steam-shovel or to the crane grab, and, owing to the limited use of the steam-navvy, only the larger firms of contractors owned such plant. Since the evolution of the dragline, and particularly of the smaller types, not only had the large contractors found it essential to operate draglines, but even the very smallest contracting and building firms would find it impossible to compete without making use of the dragline and of its offshoot, the skimmer. If they had still been limited to the shovel, even in its up-to-date form, a tremendous amount of excavation work would still be carried out by hand instead of by machine. For instance, previous to 1924 his own firm owned one or two steam-shovels, but they were em-

ployed only on big works of a heavy engineering nature. Now they operated approximately fifty draglines as compared with only six shovels, and the great majority of the draglines were in use, not on real constructional engineering works, but on small road, drainage, and building-foundation contracts, which previously would have been carried out by hand.

Mr. Davidson had already spoken of the cableway-draglines. Those tools were, of course, limited in their application; in other words, it was necessary to have a job to suit them, but where there was not less than, say, 200,000 cubic yards to be shifted a distance within their span, which might be about 800 feet or so, there were no better machines for the job than cableway-draglines. The cost of laying the very heavy tracks necessary for the machines, together with the cost of erecting and dismantling the towers, necessitated a fairly large amount of excavation in order to absorb the initial charges. It was interesting to note that the rope renewals cost considerably more on cableway-draglines than on ordinary draglines, the reason for that being that the ropes were dragged along the ground much more than was the case with orthodox machines. The cost of rope renewals varied greatly, depending on the nature of the soil being dug; it might range from ¼*d*. per cubic yard in normal conditions to 1*d*. per cubic yard where the soil was of an abrasive character.

The Author had mentioned how the dragline could be used with efficiency for rehandling excavated material. A further example of its use in that way was when a soft material, such as mud, was delivered at a tip in rail or road vehicles. It was then found very difficult to maintain a road or a railway on the soft material in order to tip direct on to the bank. The dragline, standing on firm ground alongside the tip, made a small gullet adjacent to the road or railway, into which the vehicles tipped their load, and the dragline then dug the soft material and threw it up on to the tip. That method of forming a bank or tip with soft material saved a great amount of money, which would otherwise be spent on platelaying or on the maintenance of roads.

Mr. F. W. Ireland observed that the development of the dragline in the last few years had been wonderful; it was now extremely efficient, and its users tended to take it for granted. The Paper, however, tended to make them consider whether they were utilizing the plant with the greatest efficiency, particularly, he thought, in regard to changing the bucket. The bucket was a part of the dragline which had been developed considerably, due mainly, he thought, to welding having been utilized a good deal in recent years, but he still felt that there was room for improvement. When a dragline was digging gravel, for instance, it did not appear to fill the bucket to the advertised capacity, but only to the extent of about 60 or 70 per cent. of that capacity. It was possible that buckets made to better design would hold more material in proportion to the advertised capacity, and it might also be possible to design a bucket in

which sticky clay would not accumulate and require the attention of the banksman.

The tower-scraper had already been mentioned. Except under very favourable conditions, it struck him as being a rather expensive machine to use for excavating. It was, he thought, very expensive in first cost, it took a long time to erect, and the track was expensive. He thought a comparison of costs as between a tower-scraper and a diesel-engine drag-line would be of interest. A disadvantage of the tower-scraper seemed to be that it did not travel very quickly as compared with its digging powers, and that meant that there was a tendency to get a large accumulation of spoil in one spot, which was not required in a bank. He thought also that when men were paid on the bonus system there was a tendency for spoil to accumulate still more, because with more travelling there was less digging!

There were other forms of excavators which were to some extent superseding draglines nowadays, where the conditions were suitable, and possibly at some future date comparisons of costs with those might be available.

Draglines were now being much used on big irrigation works. The Author mentioned in his Paper the Sukkur barrage in India, which gave a tremendous scope for the use of draglines. As far as he remembered, in that area there was a rather light soil and the conditions were very dry, and the Author quite rightly said that steam could not compete there with diesel drive. He had not had actual experience of the Sukkur Barrage scheme, but he had had some experience of works on a canal in south India, and it was found that coal could not very well be used there. It had to come about 1,000 miles and was of extremely poor calorific value, and water was sometimes difficult to obtain. Another factor to be taken into consideration was that coal and petrol tended to disappear, as they had a marketable value in the bazaar, whereas diesel fuel had not much marketable value there. In the case of the canal in south India to which he had referred, he thought that about 90,000,000 cubic yards of soil had been shifted. Two diesel-electric machines were used, with caterpillar tracks, one working down each side of the canal, and they did very good work. The cost was a little high, but in a country like India there were difficulties which added to costs. An interesting point was that until 1918, although the machines were obtainable, they could not compete with coolie labour; after the war, however, coolie wages were increased and then the position was altered. Excavating work in India could be compared with coal mining in Great Britain; it was a staple industry, and when draglines were adopted a great many coolies were thrown out of work.

He did not think that there was in the Paper any comparison of the output and costs of diesel draglines and steam draglines in Great Britain. It was possible that under present conditions a return might have to be

made to steam if diesel fuel were difficult to obtain. Some years ago he had had the opportunity of seeing steam and diesel draglines working side by side, and the diesel dragline gave about 20–25 per cent. greater output in a shift. He did not remember how the costs compared, but it would appear that the diesel machine would be better in that respect.

Mr. H. C. Erith said that 4 years ago he had seen the 6-cubic-yard dragline shown in *Fig. 11* (facing p. 26), and he had been interested to see that the Albert canal in Belgium had been mainly excavated by a very large continuous-bucket excavator. Such machines were very largely used throughout the Continent, and, whilst there were very large excavating jobs in the United States, it was well-known that the brown-coal industry in Germany was greater than any other excavating job in existence. One concern alone had thirty-six different machines, the average weight being 700 tons, and they were excavating a prodigious quantity of material, both very dense overburden and the brown coal or lignite itself. For that class of work the continuous-bucket land-dredging machine was absolutely universal, and he was very much impressed with the land-dredger in various other types of work. Curiously enough, however, it had never been generally adopted in the United States. The leading Continental firms made dragline excavators, but they all supplied multi-bucket excavators for the brown-coal industry.

He was very interested in the " walking " dragline, which he knew had been made in America for 27 years, from the small sizes such as those of $\frac{3}{4}$-cubic-yard bucket capacity, up to the 15-cubic-yard machine. The lifting and tilting motion known as " walking traction " was very ingenious, but he could not help thinking that that variation of the tractor motion was a somewhat similar case to the fluid flywheel for motor-cars, in that it was an ingenious and useful talking point for a salesman, but was not really of great importance. It was shown throughout the Paper that even the largest machine could be furnished with the ordinary crawler or caterpillar tractor.

He wished to draw attention to a Lecture delivered to the Students of The Institution by the late Sir Henry Japp, M. Inst. C.E., in December 1934*, which was prepared from the impartial standpoint of the user and covered the whole range of excavators of every kind. It would be within the memory of most of the members, but it was a Lecture which was very well worth referring to. There were, of course, many cases in which draglines had to be used, as, for instance, the ironstone deposits mentioned in the Paper, where the surfaces were undulating and in pronounced steps, so that the earth cover could be removed by draglines without disturbing the ironstone underlying it.

Fig. 20 (facing p. 34) showed a crawler dragline working an irregular and very steep face of Fletton clay at Peterborough, but in the same area

* The Institution Lecture to Students, 1934–35. "Modern Methods and Plant for Excavations." The Inst. C.E., 1935.

a multi-bucket excavator had worked most successfully for 10 years. It cut a smooth face on an angle of 45 degrees, which prevented landslides —a very important matter—while its series of small buckets allowed a perfect mixture of the successive strata, which was hardly obtainable with a single-bucket machine; and when boulders were encountered, as they very often were, they were easily dislodged and rolled down the slope and could not be carried on to the grinding mills.

There was one other point which he wished to mention. The price paid for excavating sand and silt with "walking" draglines for the irrigation canal in California referred to in the Paper, namely, 6*d.* per cubic yard, seemed enormously high in comparison with prices paid for similar work in Europe carried out with multi-bucket excavators.

Mr. Norman Brocklebank said that he had the privilege of attending the meeting as a deputy for Mr. Philip D. Priestman, who could not be present himself. The Author's Paper, and the lantern-slides and cinematograph-film which he had shown, displayed a highly-specialized knowledge of a field of excavators in which the firm with which Mr. Brocklebank was associated had no part; consequently his great interest in the subject was very largely academic. The firm that he was very glad to be representing that evening were specialists in the manufacture of excavators for the smaller jobs. The firm had been connected actively with excavation work since 1876, when the first grab was built for the salvage of treasure from a sunken Spanish galleon. The idea was originally conceived by Mr. William Dent Priestman. The grab built was a very primitive affair, but, although the treasure did not materialize, the grab certainly came to stay, and it was the original predecessor of the thousands of sizes which were in use to-day. From that time until the year 1921, when the first British all-purpose excavators were built, and later up to 1932, when his firm were building the smaller excavators of the 7½-ton type, they had always been directly connected with land-drainage problems and had now accumulated a very large number of statistics, not only on fen work and general river work, but also on excavation jobs, in Cumberland, Westmoreland, and North Wales, of a very rough and heavy character, which previously would have been unsuitable for small machines.

With regard to the slack-line cableway, which had been referred to in the course of the discussion, his firm had found it possible on several occasions to adapt the ordinary standard type of dragline for that work by fitting very long hoisting and dragging ropes and by forming the anchor on the opposite side of the waterway on a mobile tractor. They had thus been able to work without the normal restrictions which were imposed by the length of boom as a slack-line cableway, and still to preserve the mobility of the land dragline and the nature of the dragline as an all-purpose general-utility tool.

Another point mentioned in the course of the discussion was the difficulty encountered occasionally by clay sticking in the dragline buckets.

In that connexion he might mention that his firm had experimented with timber-lined buckets, following the example of drainage engineers, who used wooden sludging spades because of their ability to discharge the mud, and also buckets of special taper design, which had to some extent overcome the difficulty, except in the case of the most adhesive materials.

Finally, there were a few very minor points arising out of the Paper which he wished to mention. The first related to *Figs. 19* (p. 33), which illustrated the method by which the dragline could be employed to augment the use of the shovel, when the latter was not able to top the limit of the face. It appeared to him from the diagram that the dragline was having to work on the finished level and thus to rake down the material from the higher level to the lower bench, and it was his feeling that the dragline should have been standing on the top of the excavation, and should therefore be shown ahead of the shovel.

His second point was in connexion with the already-discussed item of working costs, which were given in Table II (p. 21) for various sizes and types of excavators. It appeared that the ¾-cubic-yard diesel dragline showed lower costs of excavation than the 2-cubic-yard diesel machine. Probably that was an isolated case, but he would be glad to have the Author's comments upon it, because his firm had found in almost every case that they could not avoid a rise in costs with a reduction in the size of the machine, owing to the fact that output was bound to go down at a greater rate than capital cost and running expenses.

The last point he wished to mention was with regard to the "walking" dragline. He failed to see why the "walking" dragline was so much more capable of travelling on bad ground than the caterpillar type. Admittedly, when the machine was stationary and working it was standing on a base of very large area, and consequently gave a considerably reduced ground-pressure per square foot, but during the actual movement it appeared that the side shoes in contact with the ground gave approximately only the same ground-pressure as would be obtained by the equivalent size of caterpillar crawler.

The Author, in reply, referred first to Mr. Davidson's question regarding the maximum economical depth to which excavation could be carried out in the case of a machine with a 1-cubic-yard bucket excavating dry loam or ballast. Irrespective of the size of machine, the most economical digging depth would depend upon the length of cut necessary to fill the bucket efficiently at the normal digging speed, so as to reduce the digging time in a cycle of operations to a minimum. The thickness of cut should be controlled so that the normal digging effort was exerted on the teeth at the maximum normal digging speed; in other words, the thickness of cut taken should not be so thick as to slow down the digging speed nor be so thin that the bucket was not filled at the end of the cut. The thickness of cut depended on two factors: the nature of the material,

and the angle of the working face. If the latter were too steep the digging efficiency of the bucket due to its weight would be affected, as referred to at the top of p. 15; the easier the material the thicker the cut, and the shorter the digging length that would be necessary to fill the bucket. Bearing those facts in mind and assuming a modern dragline fitted with a standard medium-weight bucket, the Author considered that the most economical digging depth in easily-excavated loam or loose ballast would be 6–7 feet. That meant a digging slope of about 20 degrees and a cut from 6 to 7 inches thick over a length of about 16 feet, to fill the bucket. With regard to the ranges above and below that figure, it was unlikely that any differences in output would be noticeable between depths of 3 feet and 8 feet. It had to be remembered that the deeper the face the longer it took to hoist and lower the bucket into and out of the excavation, but that did not matter so much providing that the hoisting speed was such that the bucket reached its dumping height at or before the end of the swing, which meant skilfully co-ordinating the two motions. It was also assumed that the material, loam or ballast, was uniform throughout the digging depth, as frequently material was heavier and more compact at lower depths, and in consequence was more difficult to excavate.

With reference to Mr. Davidson's comments regarding light welded booms, it might be of interest to know that the latest development to combine strength with lightness on long welded booms for large machines was to include steel tubing in their construction.

It was difficult to make the units of costs in Tables I (p. 20) and II (p. 21) the same, as Table II was extracted from Mr. B. J. Huntsman's Paper on the Salonika Plain Reclamation Scheme [1] and the Author had no information regarding the value of the cent. In any case the alteration would be of no real value as the Author had carefully pointed out that the cost figures were only given to compare the costs of different types of dragline on the same job.

In regard to the maximum size of draglines, the Author had mentioned, when introducing his Paper, that since the information about the world's largest dragline shown on p. 38 had been printed the latest model of that machine carried a 20-cubic-yard bucket on a boom 200 feet long. That brought that particular machine into line with the statement on p. 13.

The tower-scraper which Mr. Davidson referred to was not strictly the type of dragline excavator dealt with in the Paper. It was manufactured under various names, such as the "Tower Excavator," the "Slack Line Cableway Excavator", and the "Power Drag Scraper." At one time very large machines of that type were used on the Mississippi Levee Construction Schemes. Some of those machines had their towers mounted on caterpillar tracks. They weighed up to 300 tons, each with scraper-type buckets of 10 cubic yards capacity and with working spans of up to

[1] Journal Inst. C.E., vol. 5 (1936–37), p. 243 (March 1937).

1,000 feet. Within recent years, however, they had been superseded to a large extent on those schemes by large "walking" draglines and tractor-drawn scrapers. It was of interest to note that Mr. Borer applied the scraper principle to the machine he referred to for dragging material up on to the bank in front of a dragline. That principle was frequently carried out in one form or another on drainage jobs. One firm, in particular, in Great Britain used a rotary form of scraper or scoop which was hauled backwards and forwards across a river or drain by means of traction-engines of the cultivator type.

In reply to Mr. Borer, the Author's statement that the dragline was developed in America was quite correct. The development, commencing in 1904, was illustrated and described in the Author's book, "Excavating Machinery"[1]. The first draglines to be used in Great Britain were Bucyrus machines imported from America in 1914–16. Messrs. Sir Robert McAlpine and Sons were the pioneers in their use, and they ordered two machines in 1914; the first, mounted on rail wheels, was used on a railway contract at Cuffley, and the second, on caterpillar tracks, on a new works near Derby. Two were also ordered by Messrs. S. Pearson & Sons in 1916 for use at Gretna. Another was purchased by Messrs. Sir William Baird & Company in 1916 for stripping iron-ore on the island of Raasay. The first dragline to be constructed in Great Britain was made by Rustons in 1918, and was originally intended for use on the coprolite workings near Cambridge. Before it was completed, however, the armistice was signed and it was sold to Mr. Harry Fairclough of Warrington, and was used by him for throwing up retaining banks alongside the Manchester Ship Canal. That machine, as well as several of the early American machines, was still in active service in Great Britain.

The Author agreed with Mr. Borer that the catchment boards had been largely responsible for "stretching" the boom lengths on certain sizes of machines, but he thought that the safety limit had been reached, at any rate as far as standard machines were concerned. He believed, however, that the longer and wider caterpillar tracks, which were now available on many sizes of machines, could, with advantage, be used on drainage work to a greater extent than they were at present, to provide greater stability on soft ground.

With reference to Mr. Borer's contention that steam power was better than diesel power for grabbing work, there was no reason why that should be, provided that the diesel engines were of ample power—that was of great importance—and that the clutches were correctly designed for easy operation to transmit easily the requisite power.

Concerning the net working time of steam machines, the figures given were from actual experience on many jobs in many countries. The loss of time included getting up steam before starting work in the morning,

[1] Published by Ernest Benn, Ltd., London, in 1928.

shortage of steam due to bad firing, waiting for supplies of coal or water, or both, and frequently the use of unsuitable coal and water, and in winter time the freezing of water-supplies.

The Author thanked Mr. Borer for his very interesting contribution to the discussion from a catchment engineer's point of view.

The Author thanked Mr. Henry for the information that out of fifty-six excavators that his firm were operating, fifty of them were draglines, which was an excellent proof of the general utility of the dragline excavator. Mr. Henry's reference to steam machines recalled the fact that great prejudice existed at one time amongst contractors in favour of steam machines. It was granted that steam was the ideal power for easy control and flexibility, but the loss of time and the difficulty often of obtaining ample and suitable supplies of coal and water more than outweighed those advantages.

With regard to the economical loading of a dragline bucket in gravel, referred to by Mr. Ireland, that was always an annoying point, especially if the material were waterlogged, or excavated from under water, as a percentage of the material was almost always washed out of the bucket. Special buckets had been designed and patented from time to time, fitted with hinged doors which fell down over the mouth of the bucket to prevent the material from being washed out, but they had not met with much success. It was, however, fairly common practice to supply specially deep buckets for those conditions, or for users to fit standard buckets with collars to increase the carrying depth, especially at the back, but probably the easiest solution was to fit a larger-capacity bucket to make up for the smaller loading of the usual standard bucket.

It was difficult to cater for sticky clay and to avoid it accumulating in the bucket. One of the features of the modern bucket was, however, the fact that it dumped cleaner than the older types. That had been effected by well rounding the corners, and by the use of welding, which dispensed with rivet-heads and resulted in generally smoother construction inside.

A tapered bucket did not, unfortunately, overcome the difficulty, as, unlike the bucket of a shovel, a dragline bucket was discharged from the open end or mouth, so that if it were tapered to assist dumping, the material would wedge in the back or tapered end when filling. If the clay were very sticky it was useful, when water was available, occasionally to swill the bucket out with water, as the Author had seen contractors swill out shovel buckets when dealing with "bungum." Occasionally he had seen dragline drivers drop the dragline bucket into a pool of water when one was within reach.

Mr. Ireland was correct in thinking that most of the excavation on the Sukkur barrage had been in rather light soil, although there was, in some places, a proportion of hard clay, and in others sand almost as fine as pepper, which enveloped the draglines in a smoke-like cloud.

Regarding the comparison of the output and costs of diesel draglines

and steam draglines in Great Britain, the Author had no comparisons similar to those given in Table I (p. 20), which were taken from Indian reports. The outputs from diesel draglines were usually greater over a period than those from steam draglines, chiefly because the average net working hours were greater on the diesel machines, although the time taken to complete a cycle of operations was approximately the same.

It could be confidently stated, however, that working costs were lower with diesel machines, because the fireman on a steam machine was dispensed with on a diesel machine, and the cost of diesel oil at £5 per ton was from one-quarter to one-fifth the cost of coal on a steam machine with coal at 30*s*. per ton. Depreciation and maintenance charges were rather higher on a diesel machine than on a steam one. Taking everything into consideration, the cost per cubic yard using a diesel dragline would probably be from 25 to 30 per cent. less than with a steam machine.

Referring to Mr. Erith's comments, the Author thought that his enthusiasm for endless-bucket excavators, or land-dredgers, as they were sometimes called, was not consistent with the real facts. There was no better nor more economical type of excavator when the working conditions were suitable—such as, for instance, when it was working in reasonably dry uniform material, similar to that in the German brown-coal mines referred to by Mr. Erith. The endless-bucket excavator was not so popular on the Continent as it had been. It was not, of course, a novelty in Great Britain, as several machines had been used on the Manchester Ship Canal 50 years ago, and their good and bad features were fairly well recognized by most engineers. The Author knew, however, of more failures of that type of excavator than of all the other types added together. Some of those failures were worth recording. It should also be noted that all the failures mentioned were with large machines that had been purchased either by engineers after a conducted tour of Germany, or as a result of the engineers' recommendations following such a tour.

Before draglines were used upon Indian irrigation schemes a number of large endless-bucket excavators had been purchased and discarded after a short experience with them in sun-baked clay. That costly experience had made it difficult, for a time, to convince some of the engineers in India that it was the type of machine that was at fault and not the principle of excavating machines, for conditions in India.

A large endless-bucket excavator purchased for excavating chalk was another failure owing to the unsuitability of the material.

Within the last few years three endless-bucket excavators near Bedford, two for digging brick clay and one for stripping, had proved costly failures. All three of those machines were successfully replaced by draglines. In one works the output of bricks was increased by 30 per cent. within a week of the installation of the dragline, because the clay excavated by the dragline was drier and there were fewer stoppages due to wet clay and bad weather.

Mr. Erith was quite correct in his statement that an endless-bucket type of excavator had been digging brick clay successfully in the Peterborough area for 10 years. It was equally true that since that excavator had been installed the engineer responsible for purchasing and using the machine had purchased two draglines for two new clay pits, not, however, because the endless-bucket machine in his first pit was a failure, but because the working conditions, including a bed of stone in the clay, were not suitable for endless-bucket excavators. One of those engaged in deep digging had been illustrated during the introduction of the Paper at the meeting.

It was far from correct to state that the big Albert Canal was mainly excavated by a very large endless-bucket machine, as only a very small percentage of nearly 3,000,000 cubic yards was excavated by that machine. Over fifty excavators of various types were used on the Albert Canal, of which three were endless-bucket machines and the remainder shovels, draglines, and grabbing cranes.

Referring to Mr. Erith's statement that the leading Continental firms made dragline excavators as well as endless-bucket machines, the Author had no knowledge that Messrs. Krupps, Siemens-Schuckert, and Lübecker manufactured draglines.

The Author could not confirm Mr. Erith's contention that "walking" draglines had been made in America for 27 years with capacities as small as $\frac{3}{4}$ cubic yard. Although small machines, having a capacity as low as 1 cubic yard, had formerly been listed, very few were made. The smallest size listed at present had a capacity of 2 cubic yards. The Author did not think that the "walking" device would be available on machines smaller than that, as caterpillar tracks provided greater mobility.

Mr. Erith suggested that the "walking" device was not of really great importance and was only an ingenious and useful talking point for a salesman. It was worth pointing out, however, that the low bearing-pressure which it exerted on the ground was only one of its advantages, for it was clear that longer booms or larger buckets, or both, could be fitted to a walking dragline than was the case with a caterpillar machine of the same weight. Alternatively, if certain ranges and bucket capacities were specified, a caterpillar-mounted machine would necessarily be larger and heavier, and usually more expensive. Its ability to "sidestep" on certain jobs such as levee construction was also useful. The main point was, however, that the "walking" dragline had advantages for certain jobs, just as the endless-bucket machine had for others.

Finally, the Author did not think that any contractor would consider 6*d*. per cubic yard to be "an enormously high price" with any plant, especially when it was borne in mind that the price of 6*d*. not only included digging the material but putting it into the banks. It should also be borne in mind that costs, generally speaking, were higher in the United States than in Europe.

Mr. Brocklebank suggested that the Paper and the lantern-slides shown at the meeting dealt with excavators in which his firm had no part, but the Author pointed out that two of the illustrations used by him, including one of the lantern-slides showing a dragline in the Malayan jungle, were of machines made by Mr. Brocklebank's firm. The ¼-cubic-yard dragline mentioned in connexion with the working costs given in Table III (p. 22) referred to another machine made by Mr. Brocklebank's firm.

The Author thanked Mr. Brocklebank for drawing his attention to an error in *Figs. 19* (p. 33). The dragline shown in the plan should have been shown at the bottom of excavation B, and its position would then have coincided approximately with the dimension 45′. Working thus the dragline followed the shovel as shown, but dragged down the material B in a similar manner to the dragline in *Fig. 18* (facing p. 33), which was dragging down the upper portion of the overburden or cover.

The Author regretted that he was unable to explain the reason for the low working cost of the ¾-cubic-yard diesel dragline given in Table II (p. 21), as compared with the larger diesel draglines, as the figures were taken, as stated, from a Paper by Mr. B. J. Huntsman, and the Author did not know the conditions under which the machines worked. Those conditions would probably account for the unusual difference in cost, because, as Mr. Brocklebank correctly pointed out, the excavation costs of small machines were almost always greater than those for larger machines.

Regarding the "walking" dragline, the Author did not know of any claims that the machine was so much more capable of travelling on bad ground than a machine of the caterpillar type. It had, however, a definite advantage when working on soft ground, as it was then that a machine tended to sink in; that was because the vibration and the movable varying loads upon the base or caterpillar tracks, acting for some considerable time, caused the ground to give way. A machine could frequently travel safely over ground into which it would sink if it were excavating.

Referring to the probable pressure on the walking-shoes when the machine was travelling, the fact that about half the weight of the machine was taken on the trailing edge of the base should be taken into consideration.

⁂ The Correspondence on the foregoing Paper will be published in the Institution Journal for October 1940.—Sec. Inst. C.E.

BRITISH–AMERICAN ENGINEERING CONGRESS, 1939.

The following Paper, dealing with conditions in Great Britain, was to have been presented at the British–American Engineering Congress at New York in September, 1939, and was therefore primarily prepared for reading before American engineers.

"British Road Development, and its Effect on Modern Practice."

By John Gordon Pidgeon, Assoc. M. Inst. C.E.

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Introduction.

It is probably not an exaggeration to state that the invention of the internal-combustion engine has influenced the course of civilization just as much as did the introduction of the steam engine three-quarters of a century earlier. Its application to road vehicles at the beginning of the present century, and the rapid subsequent development of that process—more particularly during and since the Great War of 1914–1918—has presented the highway engineers of Great Britain and other civilized countries with a complex but interesting problem. So far as Great Britain is concerned, the problem consists to a large extent of the adaptation to the needs of modern motor traffic of the ancient and haphazard network of highways, which has been gradually brought into being by the changing modes of travel throughout a period of some 2,000 years.

There were in 1938 on the roads of Great Britain 3,093,884 licensed motor vehicles, in relation to a total population estimated at slightly in excess of 46,200,000, which is equivalent to about 1 vehicle for every

15 persons. No useful comparison can be made between British highway problems and those met with on the American continent unless it is borne in mind that Great Britain is the most densely roaded country in the world, the total mileage in relation to area being double that of the United States. There are, moreover, about 17 vehicles per mile of road in Great Britain, compared with about 10 per mile in the United States. Coupled with this is the even more fundamental difference that about 95 per cent. of the 179,600 miles of roads in Britain are metalled or surfaced with impervious materials, whereas a very large proportion of the roads in the United States are presumably still of earth or gravel.

A further circumstance which has an important influence upon the relative traffic conditions in the two countries is that the population is much more evenly distributed in Great Britain than in the United States, with the result that there are in the former case less violent fluctuations of traffic density as between the rural areas and the environs of towns. This probably accounts for the greater popularity in Great Britain of the pedal-cycle and the motor-cycle as a means of road travel. These vehicles contribute very largely to the deplorable toll of the road, and it will be shown elsewhere in this Paper that casualties and personal injuries are greater amonst pedal-cyclists than amongst any other class of vehicle users.

No doubt the authorities responsible for highway administration in the United States and Canada have their peculiar problems and difficulties, and in respect of higher speeds in open country and greater congestion in built-up areas they must be greater than those of the British authorities. On the other hand, they are fortunate in being able to deal with the accident problem without the complications which arise from having to provide for pedal-cycles and pedestrians. It will be obvious that not only have these factors an important bearing upon the general question of road safety, but that they also exert considerable influence on design, because the absence of cyclists and pedestrians permits a simplicity of layout and an economy of construction which would be impracticable if it were necessary to take them seriously into account.

Historical Review, and the Evolution of Administrative Machinery.

It will perhaps be appropriate to introduce here a brief sketch in broad outline of how the present intricate network of highways in Great Britain has grown from its earliest beginnings, in the period prior to the Roman conquest (which began in the year 43 A.D.), up to the present day, and how the machinery whereby the roads have been administered and maintained has been gradually evolved, in spite of numerous vicissitudes occasioned by social, political, and other influences.

The six main epochs into which the history of British land-communications may be sub-divided are as follows :

(1) The period of the Roman occupation, covering approximately the first 4 centuries of the era under consideration.

(2) The "Dark Ages," of a little over 6 centuries, when in Britain, as elsewhere in Europe, the deterioration of the roads and other evidences of civilization followed the withdrawal of the Roman legions.

(3) The "Middle Ages," which are usually regarded as the 5 centuries between the Norman conquest and the Reformation. On the whole this was a period of revival in social development (as witness the numerous stately cathedrals and substantial and beautiful bridges which date from that time), but it was unaccompanied by any marked improvement in the means of communication.

(4) The turnpike and stage-coach era, which lasted from the middle of the seventeenth century until the invention of the steam locomotive early in the nineteenth century.

(5) The period of the great industrial revolution and the advent of the railways, which to a large extent supplanted the canals and administered a setback to road improvement.

(6) Lastly, but not least in order of importance, the present era, the age of speed and of intensive development in facilities for travel by road and by air, due to the invention of the internal-combustion engine, to the possibilities of which no limit appears to be in sight.

Fig. 1, Plate 1, is a map showing approximately the system of military roads constructed by the Roman engineers during their long occupation of Britain. The work which they accomplished constitutes a unique example of road-planning on a bold and comprehensive scale.

In forming their plan of construction the Romans evidently had as their primary objectives points of military importance, such as Lincoln, York, and Chester, suitable for further operations along ever-extending frontiers. They doubtless took advantage of the lines of existing track-ways, and of the local knowledge which would long previously have determined such factors as the best crossing-point of a river, or the easiest track through swamp or forest. Whilst they paid little attention to gradient, they had a wonderful eye for country, but in other respects physical conditions were perhaps the dominant factor, and it is significant to note that the ancient Roman roads and the present main-line railways were located along approximately parallel lines.

The Roman roads were the root of the whole highway system of Great Britain, and in later centuries local roads emerged slowly from the original skeleton or framework which they formed. All subsequent improvements in communication grew from them, for it is fair to state that, with the exception of the canals, there was no really new development on a national

scale between the planning of that military system and the coming of the railways.

The directness of Roman methods is well illustrated by the practice which their engineers adopted of driving the roads for the most part in straight lines from point to point. They had a character and structure which they have retained to the present day, for even in the straightening or strengthening of an old trackway upon which it was founded, the road would bear the mark of the Roman engineers throughout all that remained of its course.

The great highways built by the Romans were later given distinctive names by the Saxons, the Roman names (if any) being unknown. Notable examples are Watling Street (from Dover *viâ* London and Wroxeter to Chester), Ermine Street (from London *viâ* Lincoln to the Humber), Stane Street (from Chichester to London) and the Fosse Way, which runs from Lincoln, in a south-westerly direction, to Seaton, on the southern coast of Devonshire. It is estimated that at no point between Lincoln and Axminster (a few miles north of its southern terminal point) does the route of the Fosse Way deviate more than 6 miles from a straight line between those places, which are over 180 miles apart.

The thoroughness of the constructional methods employed will be appreciated from the following description of a portion of the same road, based on excavations made about 10 miles from Bath some years ago.

"1. *Pavimentum*, or road bed of fine earth, well beaten in.
"2. *Statumen*, or foundation, composed of large stones, sometimes mixed with mortar, carefully fitted by hand.
"3. *Ruderatio*, or small stones, well mixed or grouted with mortar.
"4. *Nucleus*, formed by mixing lime, chalk, pounded brick or tile; or gravel, sand and lime mixed with clay.
"5. Surface of the paved road, technically termed the *summum dorsum*."

The Romans varied the construction of their roads according to the materials and the amount of traffic they might be expected to carry. In swampy districts piles were driven or brushwood laid to form an artificial base on which to carry the large stones referred to in (2) above. The rubble referred to in (3) would be about 9 inches thick, and the layer above it, (4), about 6 inches thick. In the best work the surface pavement consisted of flat slabs of the hardest stone available, carefully fitted and cemented together with a cambered profile, and held in place by curbing.

The departure of the Romans was followed by a state of insecurity during which the civilization of the country rapidly deteriorated, as was the case over the whole of Europe. The road system, in common with the other institutions which they had founded, fell into disuse and decay. The country was no longer held as one province by a network of strategic roads, but was split up into petty kingdoms, by whose peoples means of

intercommunication were probably regarded more as a source of danger than as a convenience.

After the Norman conquest such responsibility as existed for the control and administration of highways rested mainly upon the landowners, of whom the religious Orders formed a very large proportion. At about this time there first emerged the conception of the " King's Highway ", carrying with it the right of passage by all the King's subjects. The sovereign was, however, only concerned with the security of those who used the highways, and not with their maintenance.

Although a large number of interesting and beautiful old bridges (some of which embody unique features such as chapels, and towers for defensive purposes) date from this period, the general condition of the roads suffered greatly from the lack of a central directing influence, and it is probably true to say that the monasteries were the only bodies with any sense of corporate responsibility for the welfare and direction of the traveller.

The common-law liability to keep the roads open and in repair rested upon the Lord of the Manor, but road communications were regarded almost entirely from the point of view of local convenience. Thus it came about that the network of highways and byways which now covers the land came into being for the most part with neither definite aim nor continuity of purpose—in one place perhaps following what may have been originally a track for sheep or cattle, elsewhere making a long detour in order to conform with the boundary fence of some powerful lord, or to serve as a connecting link between isolated dwelling places long removed from human ken. Consequently the work of the British roadmaker became to a large extent one of adaptation, making the best of what his predecessors had left him, hampered as to width by enclosures and encroachments, and tied as to alignment by the haphazard happenings of bygone ages.

The first example of English highway legislation was the Statute of Winchester in 1285, which required landowners to keep in proper repair the roads within their estates, although in fact there was little public demand for roads suitable for wheeled traffic. The dissolution of the monasteries by Henry VIII in 1536–39 contributed to the neglect of the road system by removing the only corporate bodies which concerned themselves with bridge building and road maintenance. An illustration of the state of affairs existing late in that reign was the enactment that, when a track became founderous, it could be abandoned and another beaten out alongside.

Conditions became so bad that Parliament was eventually forced to take action, and an Act passed in 1555, in the reign of Queen Mary, constituted the first effective legislative effort in the direction of road improvement. It placed the obligation to repair the roads on the parish. Householders of £50 annual value were required to provide tools, carts, and horses, whilst every occupier, cottager, and labourer had to work on the

roads for at least 4 days per annum. The supervision of the work was entrusted to a person elected by the parish; it was his duty to make three inspections per annum and to rise in church after the sermon on the ensuing Sunday to call the attention of offenders to any defect for which they were liable.

In Queen Elizabeth's reign, in 1563, an Act was passed increasing the number of days of statute labour from 4 to 6, and giving the local justices power to indict a parish for neglect. Early in the seventeenth century the influence of wheeled traffic upon the social and economic development of the country began to manifest itself, but unfortunately it was accompanied by the passing of legislation which had the result of seriously limiting its effective use. The ruling idea was to make the traffic suit the roads; for example, an Act of 1621 prohibited the carrying of any load exceeding 1 ton in weight, whilst numerous restrictions were placed upon the number of draught-horses, the widths of tires, and so forth.

The accession of James VI of Scotland to the Throne of England in 1603 led to a marked increase of travel between north and south and to demands for the improvement of road communications. The first Turnpike Act was passed in 1663, and so began the period of activity in highway planning and construction known as the turnpike era, which flourished until early in the nineteenth century. The effect of the turnpike was to give to authorized trusts the right to develop the use of selected principal highways and to collect tolls on the vehicles using them, thus earning interest on the money invested. In 1838 there were eleven hundred trusts controlling about 22,000 miles of the principal roads of the country, in addition to which there were something like 105,000 miles of parochial highways in the charge of about fifteen thousand parishes.

The first stage-coach in Britain commenced to run between Leith and Edinburgh in the year 1610, but development progressed slowly, for it was not until 1659 that this mode of conveyance appeared in England. It is recorded that the journey of 105 miles from Bath to London in the latter half of the seventeenth century occupied 3 days, and that it took 5 days to cover the distance of 180 miles between London and Exeter.

In 1749 a fast coach was running between London and Birmingham, a distance of 108 miles, and accomplished the journey in 3 days, whilst 5 years later a company was formed to run a stage-coach between London and Manchester (182 miles), and their prospectus stated with pride, "However incredible it may appear, this coach will actually (barring accidents) arrive in London 4½ days after leaving Manchester."

By the year 1775 some four hundred stage-coaches were running regularly between the large towns, and 9 years later they were entrusted with the carriage of mails, which had previously been borne by post-boys on horseback. The method was introduced of keeping relay horses at certain inns known as "posting houses."

The great activity in canal construction from 1759 onwards naturally

hindered road development, since the new system of water-carriage proved more economical, especially for heavy goods, than transportation by road. Nevertheless, the dawn of the industrial revolution towards the close of the eighteenth century demonstrated the limitations of the canals and brought the conviction to business men that extended facilities for wheeled traffic were essential to the opening-up of new markets.

The year 1810 is noteworthy in the annals of British roads, for it was then that Thomas Telford (the son of a Scottish shepherd, who began life as a stonemason and eventually became the first President of The Institution) was commissioned by the Government to undertake the task of reconstructing a length of 194 miles of the London–Holyhead road. This was the first official recognition in England of the principle that roads should be made to suit the requirements of traffic, as opposed to the idea that traffic should be adapted to the roads. It was an undertaking which called for all the engineering and administrative genius and driving force that Telford possessed. The complexity of the problem was aggravated by the fact that he was given no statutory powers to override the twenty-three English and Welsh turnpike trusts which were then controlling the road, and each of these had to be bargained with and persuaded to agree to the new proposals. The work was finished in 1830, and from that time there existed, after a lapse of some 14 centuries, at least one completely good road connecting terminal points nearly 260 miles apart. Together with the construction of the beautiful suspension bridge over the Menai Straits and the improvement of Holyhead harbour, the scheme had drawn from Parliament a payment of £750,000.

Telford's system of construction was similar to, if not based on, that of the Romans. He used a foundation of large stones, about 9 inches deep in the centre and 5 inches deep at the sides, thus obtaining his camber in a manner which differs from the more modern practice of forming a convex road-bed. The spaces between the stones were filled in with small fragments well rolled-in. On this was laid a 6-inch layer of stone, broken to pass a 2½-inch ring, which was finished with a coating of gravel, free from earth or clay.

Contemporary with this first complete model-road in England went the movement led by Macadam, who was a very able propagandist, with intense devotion to the cause of the improved road surface with which his name will always be associated. The method employed by Macadam was to spread a course of broken stone from 3 to 5 inches in thickness upon the natural road-bed, which had previously been rolled to a uniform surface. When this was consolidated, a second coat and sometimes other coats were imposed until the necessary thickness was obtained, whereupon a thin layer of binding material was washed into the interstices so as to form a compact and impervious surface.

Principally as a result of the labours of these two men, the standard of road making was so improved that in 1836 the daily mail coach covered the

distance from London to Birmingham in 12 hours and from London to Manchester in 17¼ hours. Meanwhile, the development of the railways was having its inevitable effect upon the roads, and for some years after Stephenson's first success in 1825, the suggestion was seriously advanced that the days of the roads were numbered, and that expenditure thereon could with advantage be curtailed.

The Highway Act of 1835 was the first of numerous nineteenth-century Acts from which the present-day system of administration emerged. It was described as "an Act to consolidate and amend the laws relating to highways in that part of Great Britain called England." It repealed practically all former enactments (except those relating to turnpike trusts), abolished statute labour, and authorized the appointment of salaried surveyors and the levying of highway rates, but it failed to recognize the need for a larger administrative unit than the parish. In 1848 local boards of health were created in urban districts and invested with the duties of maintaining their own public highways. The various Highway and Public Health Acts passed between 1848 and 1878 further widened the responsibility of local authorities, urban and rural, with respect to road administration.

The abolition of the turnpike system and the creation of "main" roads dates from an Act of 1878, but the greatest advance of that period occurred when the Local Government Act of 1888 brought county councils into being, imposed on them responsibility for the upkeep of all the main roads, which had ceased to be turnpike roads (subject to the right of urban authorities to maintain main roads in their own areas), and authorized the appointment of county surveyors, whose duties were primarily concerned with the maintenance and improvement of those roads. This Act also created county borough councils and transferred to them responsibility for all county roads within their respective areas. Outside the urban areas, the highway parishes and highway boards, and, after 1894, the rural district councils, were charged with the care of all roads other than main roads. A marked feature of the position existing at the end of the nineteenth century was the large number of highway authorities (about two thousand), ranging from small and sometimes impecunious urban and rural district councils to large and prosperous county and county borough councils, all without central control or guided by anything in the nature of a national policy.

The development of mechanically-propelled road vehicles from about 1896 onwards made it evident that local resources could not cope unaided with traffic, which had ceased to be entirely local in character. The first step in the direction of assistance from the National Exchequer was the constitution of a Road Board in 1909. This body was entrusted with the administration of a fund amounting to about £1,250,000 per annum, which was earmarked for schemes of national importance. The Board did useful work, but the means at its disposal were inadequate to cope with the

expansion of traffic following the Great War, and in 1919 it was merged into the Roads Department of the Ministry of Transport.

The Roads Act of 1920 created a Road Fund, which was to be raised by the direct taxation of mechanically-propelled vehicles, the proceeds to be devoted exclusively to the upkeep and improvement of public highways. For the purpose of administering the fund, the Act empowered the Minister of Transport to classify the roads of the country, which he did as from the 1st April 1921, subject to subsequent review from year to year. The most important routes were designated Class I roads, and routes of secondary importance became Class II roads, whilst the remainder were, and are still, termed unclassified roads.

In general, Class I roads and bridges are at present subsidized from the Road Fund by grants at the rate of 60 per cent. towards approved expenditure on maintenance and improvement, the corresponding subsidy for Class II roads and bridges being 50 per cent. The improvement of unclassified roads, which are principally local in character, is only assisted by occasional Road-Fund grants towards specific and approved schemes, but a " block " grant equal to about 25 per cent. of the annual cost is paid towards their maintenance.

The revenue accruing from the taxation of mechanically-propelled vehicles has rapidly increased since 1921, when it amounted to about £9,500,000, until, in the financial year 1937–38, it was little short of £36,000,000. For some years, however, the receipts from motor-taxation have been regarded as part of the general revenue of the country, and national expenditure on roads is only one of the demands made on the Exchequer for various services.

The Local Government Act, 1929, made further and far-reaching changes. Generally speaking, and subject to various exceptions and conditions, rights, and duties, the effect of this Act in England and Wales was to transfer to county councils the entire management of all publicly-maintained roads (including unclassified roads) in rural districts and of all classified roads in urban districts. In Scotland there was a similar transfer of responsibility, and the general position at the end of March 1938 was as shown in Table I (p. 64).

By the provisions of the Road Traffic Act, 1934, a general speed-limit of 30 miles per hour was applied to all roads in built-up areas. On the 31st March 1939 a total length of approximately 42,000 miles of road was subject to this restriction, of which length about 725 miles related to trunk roads, as defined in the following paragraph.

Recognition of the need for widening the areas of administration demanded by the ever-growing volume of road transport, and for greater uniformity of road conditions, led to the passing of the Trunk Roads Act of 1936. By this Act the Minister of Transport was made the highway authority " for the principal roads in Great Britain which constitute the national system of routes for through traffic." Thirty routes, formerly in

TABLE I.

Number of authorities.	Authorities.	Road-mileage.
	ENGLAND and WALES.	
1	Minister of Transport	3,271
30	London County Council, City of London, Metropolitan boroughs	2,350
61	County councils	115,078
83	County borough councils	13,751
902	Municipal borough and urban district councils	19,307
		153,757
	SCOTLAND	
—	Minister of Transport	1,188
31	County councils	21,898
24	Large burghs	1,916
171	Small burghs	871
		25,873
1,303	Total Total	179,630

Class I and having an aggregate length of 4,459 miles, were specified in the Act and designated "trunk roads." They are indicated approximately in Fig. 2, Plate 1, and represent about 2½ per cent. of the total road mileage of Great Britain. The Minister of Transport now defrays from the Road Fund the entire cost of their maintenance and improvement, but in general the executive work is carried out by the county councils and other highway authorities as agents for the Minister.

Before closing this review it is necessary to refer to another useful piece of legislation, namely, the Restriction of Ribbon Development Act, 1935, which is of fundamental importance to all concerned with highway administration. The evils associated with ribbon-development have for a long time presented a serious and difficult problem. Within recent years it has been apparent to those responsible for highway administration, no less than to those who love the countryside, that the practice of utilizing important traffic routes for building-development instead of providing estate roads for that purpose, is detrimental to the public interest.

Since the Great War a vast amount of road improvement has been carried out by widening, etc., and by the construction of by-passes and diversions. Unfortunately, this has been accompanied by a large increase in the development of highway frontages both for residential and commercial purposes, with the result that the additional highway space has too often become a parking place for vehicles and the purpose of the improvements largely defeated. Further, this form of development, often with shops, schools, factories, and residential property on both sides of the road, created a serious safety problem, which led to demands for the imposition of speed-limits.

The Act of 1935 conferred valuable powers on highway authorities. Stated briefly, it provided that no building should be erected within 220 feet of the middle of the restricted road, and no new means of access formed to that road, without the prior consent of the highway authority. These restrictions were applied by the Act to all roads that were in Class I or Class II on the 17th May 1935 (some 43,000 miles in all), and since it was passed highway authorities have by resolution brought an additional 29,000 miles under control, principally unclassified rural roads.

Traffic Statistics and the Accident Problem.

Since the year 1922 it has been customary for 7-day traffic-counts to be taken at more or less regular intervals at about 10,000 selected points on the Class I and Class II roads of the country. The last general census, that of August 1938, was applied to trunk roads and Class I roads only. It was taken at 5,279 points in the counties and 475 points in the county boroughs, but the latest census taken on these two classes of roads in respect of which a complete analysis of the traffic figures is at present available is that of August 1935. From this analysis it is of interest to note that at about 25 per cent. of the 5,141 points outside the county boroughs, the estimated average weight of traffic per day of 16 hours (6 a.m. to 10 p.m.) exceeded 5,000 tons, and that at about 32 per cent. of these 5,141 points the average daily number of vehicles exceeded 4,000, which is the equivalent of 250 vehicles per hour.

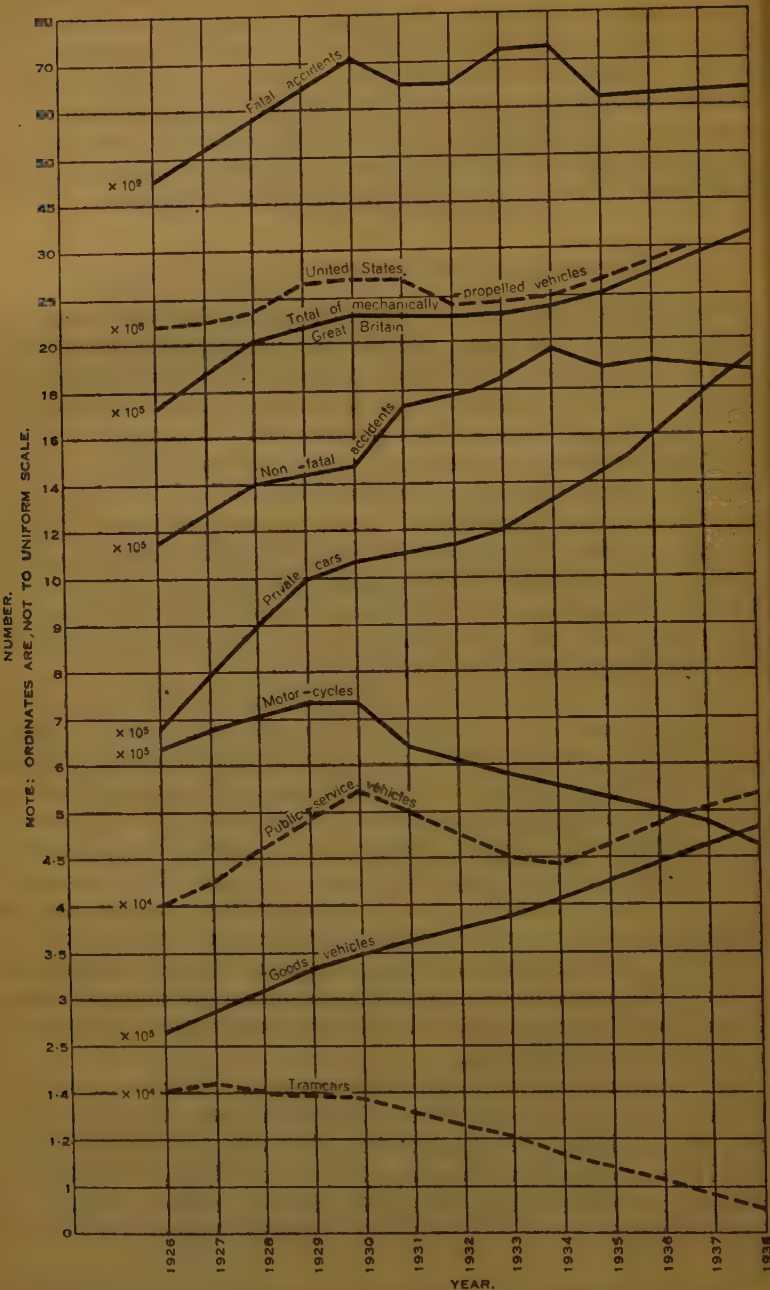
Perhaps the most marked feature of the traffic-counts in recent years has been the increase in the use of pedal-cycles, as indicated by the fact that the total number of cycles recorded during an average day of 16 hours at the 4,830 comparable points outside the county boroughs in the census of 1935 represented an increase of about 95 per cent. on the corresponding figure for 1931. The highest average number of pedal-cycles recorded at any individual point during the census of August 1935 amounted to 18,429 per day of 16 hours, that is, to nearly 20 per minute, the corresponding figure for the same point in the 1931 census being 12,502.

Fig. 3 (p. 66) illustrates (1) the fluctuations in the numbers of the various classes of licensed vehicles using the roads during the course of the past 12 years, and (2) the variations which have taken place in the accident rates during the same period.

The total number of mechanically-propelled vehicles on the roads increased from 1,729,505 in 1926 to 3,093,884 in 1938. From 1926 to 1937 there was an increase in the number of private cars from 686,232 to 1,798,105, and of goods vehicles from 257,173 to 478,922, but motor-cycles decreased in numbers from 629,414 to 487,578, hackney carriages from 100,835 to 85,766, tramcars from 14,078 to 9,657 and tractors from 3,670 to 3,167.

With the co-operation of the Home Office the Minister of Transport has

Fig. 3.



Fluctuation in Accident Rates and in Numbers of Licensed Vehicles, 1926–38.

from time to time issued reports containing analyses of road accidents, based on particulars supplied by the Commissioners of Police for the Metropolis and for the City of London, and also by the chief constables throughout the country. From these publications and other statistics emanating from the Home Office, Table II, showing the numbers of persons killed and injured during the period 1926 to 1938, is derived.

TABLE II.—ROAD-ACCIDENT STATISTICS FOR GREAT BRITAIN.

Year.	Killed.	Percentage of total.	Injured.	Percentage of total.	Total.
1926	4,886	3·52	133,888	96·48	138,774
1927	5,329	3·46	148,575	96·54	153,904
1928	6,138	3·59	164,838	96·41	170,976
1929	6,696	3·77	170,917	96·23	177,613
1930	7,305	3·94	177,895	96·06	185,200
1931	6,691	3·20	202,119	96·80	208,810
1932	6,667	3·13	206,450	96·87	213,117
1933	7,202	3·22	216,328	96·78	223,530
1934	7,343	3·08	231,603	96·92	238,946
1935	6,502	2·85	221,726	97·15	228,228
1936	6,561	2·80	227,813	97·20	234,374
1937	6,633	2·84	226,402	97·16	233,035
1938	6,648	2·85	226,711	97·15	233,359

The improved figures since the peak in the year 1934 may perhaps reasonably be attributed to the concentration of effort by the responsible authorities upon accident-prevention propaganda, coupled with preventive measures of various kinds.

It is necessary to explain that the initial report on each accident, from which all the subsequent statistics are compiled, is made by a police officer. The impartiality of the officers concerned is beyond question, but in a fairly large percentage of cases there is probably room for a difference of opinion regarding the circumstances primarily responsible for an accident. Subject to this reservation, the records that have been obtained have yielded valuable information.

Table III (p. 68) indicates the nature and general distribution of all the accidents which occurred during the year ended the 31st March 1937. It is significant to note that the proportion of the accidents involving fatal and serious injuries to the total number of accidents was much higher in areas not built-up than in built-up areas, and this presumably may be attributed to the influence of speed.

For the purpose of the figures given in Tables III and IV a built-up area is regarded as one in which a system of street lighting is provided by means of lamps not more than 200 yards apart, irrespective of whether or not such roads are subject to speed-limitation under the provisions of Section 1 of the Road Traffic Act, 1934. The records show that approxi-

TABLE III.—GENERAL DISTRIBUTION OF ACCIDENTS, 1936–37.

Classification of accidents.	All areas.		Built-up areas.		Areas not built-up.	
	Number.	Percentage of total.	Number.	Percentage of total.	Number.	Percentage of total.
Fatal . . .	6,337	3·2	3,999	2·6	2,338	5·2
Serious injury .	50,719	25·5	34,894	22·6	15,825	35·5
Slight injury .	142,006	71·3	115,507	74·8	26,499	59·3
Total . .	199,062	100·0	154,400	100·0	44,662	100·0

mately 60 per cent. of the fatal accidents and 76 per cent. of the non-fatal accidents occurred on roads subject to this limitation, and that these percentages do not materially differ from those appertaining to built-up areas as defined above.

TABLE IV.

Year 1936–37.	Percentage of total.					
	Fatal accidents.			Non-fatal accidents.		
	All areas.	Built-up areas.	Areas not built-up.	All areas.	Built-up areas.	Areas not built-up.
NATURE OF ACCIDENTS.						
Collisions :						
Between moving vehicles	32·3	25·3	44·5	38·1	35·3	47·8
Cyclist falling from cycle and struck by another vehicle	1·5	1·9	0·7	0·6	0·7	0·4
In which a vehicle and pedestrian or a passenger falling or alighting from another vehicle were involved . . .	47·0	59·4	25·8	35·3	40·8	15·9
With obstructions . .	7·8	4·0	14·2	11·0	8·7	19·3
Accidents not involving collisions	8·3	6·2	11·9	13·2	12·7	14·9
Multiple accidents (that is, combinations of any two or more of the above classes)	3·1	3·2	2·9	1·8	1·8	1·7
Total . .	100·0	100·0	100·0	100·0	100·0	100·0
FEATURES OF LOCALITY.						
Accidents at road junctions	31·7	38·8	19·6	41·7	46·9	22·9
Accidents on straight roads	50·2	50·4	49·8	46·2	45·9	47·0
Accidents on open bends .	10·3	6·7	16·5	6·4	3·9	15·3
Accidents on blind bends, steep hills, etc. . . .	7·8	4·1	14·1	5·7	3·3	14·8
Total . .	100·0	100·0	100·0	100·0	100·0	100·0

Table IV shows the distribution of fatal and non-fatal accidents, respectively, during the year ended the 31st March 1937, according to the nature of the accidents and the features of the localities at which they took place. This distribution shows little change from the figures applicable to the year 1935. Here, again, the influence of speed shows itself, since it seems reasonable to assume that it was accountable for the high percentage of accidents which occurred on straight roads or open bends, where there was no suggestion of restricted visibility.

The sole or main causes of the accidents, as assigned by the chief constables, are analysed in Table V, with comparative fatal-accident

TABLE V.—ANALYSIS OF CAUSES OF ACCIDENTS.

Number of accidents attributed to	Fatal accidents.				Non-fatal accidents.		All accidents.	
	1936–37.		1935.		1936–37.		1936–37.	
	Number.	Percentage of total.	Number.	Percentage of total.	Number.	Percentage of total.	Number.	Percentage of total.
Drivers (other than pedal-cyclists) .	2,124	33·5	1,996	31·7	64,858	33·6	66,982	33·6
Pedal-cyclists	1,051	16·6	1,038	16·5	44,317	23·0	45,368	22·8
Pedestrians .	2,470	39·0	2,562	40·7	58,145	30·2	60,615	30·5
Other persons	133	2·1	89	1·4	5,517	2·9	5,650	2·8
Vehicles or equipment .	206	3·3	235	3·7	6,940	3·6	7,146	3·6
Miscellaneous causes . .	218	3·4	217	3·5	11,278	5·8	11,496	5·8
Causes not traceable .	135	2·1	152	2·5	1670	0·9	1,805	0·9
Total . .	6,337	100·0	6,289	100·0	192,725	100·0	199,062	100·0

figures for the year 1935. This Table well illustrates the extent to which accidents generally may be attributed to the great variety in the character of the traffic on British roads.

Of the total number of persons killed during the year 1936–37, 47 per cent. were pedestrians, 22 per cent. were pedal-cyclists, and 18½ per cent. were motor-cyclists or their passengers, whilst of those not fatally injured during the same period, 32½ per cent. were pedestrians, 30½ per cent. were pedal-cyclists, and 15½ per cent. motor-cyclists or their passengers.

Table VI (p. 70) indicates in respect of the year 1936–37 for four classes of mechanically-propelled vehicles the number of each class involved in accidents, (*a*) in proportion to the total of the fatal and non-fatal accidents, (*b*) in proportion to the total number of each class of vehicle licensed,

and (*c*) in proportion to the total estimated vehicle-mileage of each class. These figures (which so far as mileage is concerned are necessarily based on certain assumptions) demonstrate the fact that the motor-cycle is the most accident-prone mechanically-propelled vehicle on the public highway, and also that private cars are less likely to be involved in accidents than commercial or public-service vehicles.

The records show that only in a small percentage of cases was mechanical failure or other defect in a vehicle, or the inadequacy or absence of lights, assigned as the sole or main cause of a fatal or non-fatal accident.

There are four thousand two hundred and ten railway level crossings on public roads in Great Britain, and, although they are admittedly a

TABLE VI.

Col. 1.	Col. 2.	Col. 3.	Col. 4.	Col. 5.	Col. 6.	Col. 7.
Class of vehicle.	Maximum number licensed in any one quarter during year 1936–37.	Number involved in fatal and non-fatal accidents, 1936–37.	Col. 3 as a percentage of total number involved.	Col. 3 as a percentage of total number licensed.	Assumed average vehicle-mileage annually.	Accidents per 100,000 vehicle-miles.
Private motor-vehicles . . .	1,642,850	98,385	33·2	5·9	9,000	0·68
Motor-vans, lorries, etc.	461,629	42,185	14·3	9·1	12,000	0·76
Pedal-cycles . .	—	87,611	29·6	—	—	—
Motor-cycles . .	505,779	40,318	13·6	7·97	6,000	1·33
Public conveyances	96,269	20,063	6·8	20·8	24,600	0·85
Miscellaneous . .	—	7,327	2·5	—	—	—
Totals . . .	2,706,527	295,889	100·0	—	—	—

potential source of danger, the accident statistics indicate that, contrary to popular belief, they are not responsible for great loss of life. The elimination of a level crossing is generally a most expensive operation, and this no doubt accounts for the slow progress made in the substitution of bridges, despite the 75-per-cent. grants from the Road Fund which are offered towards the cost of approved schemes of this character.

It is customary to record the location of accidents on accident maps having a scale of 6 inches to a mile, upon which are plotted all fatal and non-fatal accidents which have occurred over a period of time varying according to the character of the road, but sufficiently lengthy to enable reliable conclusions to be reached on the facts recorded. Generally speaking, useful results cannot be expected from such a map within a period of less than 12 months.

It is necessary, however, to guard against the error of letting it be

supposed that these records and maps are anything more than a means to an end. Whilst they provide useful guidance to remedial measures, their full value is only obtained if trained minds are brought to bear upon their interpretation, and steps taken to carry out such improvements in the roads as may in the circumstances be considered necessary and practicable. The natural sequel, therefore, to the compilation of accident maps is the maintenance of a second set of maps to the same scale. constituting a permanent running record of road improvements as they are carried out. The experience gained in areas where these maps have been introduced has shown that they are a necessary and valuable counterpart to the accident maps.

Road Design and Layout.

General.

From what has been already stated it will be appreciated that the task which confronts the highway engineer of to-day is one of considerable complexity, the administrative and economic features of which are intricately interwoven with its engineering aspects. Given the necessary funds there is no special engineering difficulty in constructing roads and bridges capable of carrying safely any traffic that modern ingenuity is likely to produce. The problem for the engineer, however, is to determine how best, within a reasonable length of time, to adapt to the requirements of the present age the roads which came into being in the manner already described, at the same time allowing for probable future expansion, all at an expenditure that will not overburden the already hard-pressed taxpayer.

In 1930 the Minister circulated to highway authorities recommendations on the subject of road design and construction. About 6 years later these recommendations were brought thoroughly up-to-date and amplified by a technical committee, consisting of representatives of the Roads Department of the Ministry in collaboration with representatives of the Highway Engineers' Associations. The result of this committee's deliberations was published by the Minister in a document entitled "Memorandum on the Layout and Construction of Roads" [1] which well epitomizes the accepted practice of that date. It is, however, a commentary on the rapid strides which modern road development is taking that the memorandum of January 1937 is already in an advanced stage of drastic revision.

Segregation of Traffic.

Mere analysis of traffic and accident statistics, however complete it may be, is of no avail unless the conclusions drawn therefrom are carefully weighed and the result applied to future policy. It is suggested that one obvious lesson to be learnt from the figures contained in the part of this Paper dealing with traffic and accident statistics (pp. 65 *et seq.*) is the urgent

[1] M. of T. Memo. No. 483. H.M. Stationery Office, London. January 1937.

need to provide for the maximum possible segregation of traffic, not only by the separation of streams of traffic moving in opposite directions, but also by separating the different classes of traffic, namely, motorists, pedal-cyclists, and pedestrians.

In the past, segregation has been limited almost entirely to the provision of footways for pedestrians on urban roads and on the more important roads in rural areas, but complete segregation inevitably involves the adoption of widths much in excess of those previously considered to be adequate, and in the last resort financial considerations will determine the practicability of achieving what is required within a reasonable length of time by the provision of modern layouts including dual carriageways, cycle-tracks, and footpaths.

Twin Carriageways.

The perfect road is one that can be traversed throughout its length at a constant speed, but under the conditions of mixed traffic which prevail in all thickly-populated countries this is rarely attainable. The retarding effect of the speed-restrictions applying to various classes of traffic and of the presence of occasional standing vehicles, coupled with the influence of road intersections and various other factors, combine to prevent the achievement of such an ideal, especially where (as has been indicated) provision has to be made on the same carriageway for motor and horse-drawn vehicles, pedal-cycles, and the crossing of pedestrians.

With so many considerations involved, it is difficult to prescribe an arbitrary figure relating to the volume of traffic at which the dual system of carriageways is necessary, but the recommendation of the Ministry of Transport on this point is that where an existing or proposed road is expected to carry four hundred vehicles at the peak hour, provision for dual carriageways is desirable, and that they are often justified solely on grounds of public safety. The peak-hour load is frequently 3 times the average hourly traffic, and sometimes even greater. In calculating the peak-hour traffic for a road on which it is not proposed to provide separate tracks for cyclists, two pedal-cycles are regarded as being roughly equivalent to one vehicle.

Throughout the period immediately following the great war of 1914–18, 10 feet was the generally accepted unit of width for each traffic-lane of a carriageway, but the Ministry of Transport have in recent years recommended that, in the design of a carriageway which comprises not more than two traffic-lanes, the unit of width should be increased to 11 feet. It is now practically standard practice to provide for carriageways 22 feet wide (two 11-foot lanes) on all roads which are considered to be of such importance as to justify the present or future construction of dual carriageways.

If in any particular case the need for double carriageways has been proved on traffic grounds or as a public-safety measure, the further

question to be examined is whether the potential traffic requirements of the road are such as to demand a layout that will allow for the future addition of a third lane to each carriageway. Where three one-way lines of traffic are to be provided for in one carriageway, 10 feet is usually considered a sufficient unit of width for each lane, and the layout of the initial 22-foot carriageways is arranged so as to permit future widening to 30 feet being effected towards the centre of the road by a reduction of 16 feet in the width of the central reservation.

This point has an important bearing on the cross-sectional layout, which will be discussed later. The possibility of future traffic requirements necessitating two 30-foot carriageways has been duly allowed for in determining the standard widths to be applied to trunk roads. This has resulted in an effective or formation width of 120 feet being adopted as the standard on which the improvement of the great majority of those roads is based.

Cycle-Tracks.

The accident record of the pedal-cyclist, which has already been noted (pp. 65 *et seq.*), speaks for itself. Cycle-tracks are of quite recent introduction into Great Britain, but despite opposition from certain quarters, their usefulness is now generally recognized, and many hundreds of miles are at present under construction or in contemplation. It is unfortunate that in and surrounding the built-up areas, where the need is greatest, it is often impossible to obtain the necessary widths for cycle-tracks in addition to carriageways and footways, whilst the frequent interposition of street junctions and of entrances to shops and houses renders their construction difficult, and their use unlikely in such circumstances.

Experience has shown that cycle-tracks should have a minimum width of 9 feet. Two-way tracks are not recommended. The best position for them is on the outer side of the carriageways so as to avoid as much as possible the necessity for cyclists to cross the main streams of vehicular traffic. For reasons both of safety and of amenity, the ideal arrangement is to place the tracks between the carriageways and the footpaths, with intervening grass verges not less than 3 feet wide. If the available width is insufficient for this, as, for example, in the case of an existing road in a built-up area, the tracks may as a compromise be separated from the footpaths and carriageways by curbing. Where cycle-traffic is particularly heavy the construction of twin cycle-tracks is sometimes justified as a measure of economy as an alternative to widening an existing carriageway, apart from the general question of segregation.

Footways.

Section 58 of the Road Traffic Act, 1930, imposes upon highway authorities a general obligation to provide on all roads footpaths sufficient for the safety and accommodation of pedestrians.

The figures contained in the section of the Paper dealing with traffic and accident statistics show that, as a class of road-user, pedestrians head the list of those killed and injured on the public highway. This emphasizes the urgent need for the adoption of all practicable measures to protect them from accident. Except in very thinly populated areas, the provision of footpaths is regarded as an essential feature of modern road design. In rural areas where pedestrians are likely to be few in number a grass verge may serve the purpose of a refuge in case of emergency, but elsewhere well-surfaced footpaths of sufficient width to enable at least two people to walk abreast are necessary.

The Ministry of Transport recommend a minimum width of 5 feet for footpaths on the outskirts of towns, through villages and on short lengths of road linking up villages, but on rural roads this width may be reduced to 4 feet. In urban areas a minimum of 6 feet is desirable in the case of residential streets, but for shopping area's widths ranging from 10 feet upwards are often necessary.

Cross-sectional Layout.

In addition to giving highway authorities control over frontage development, the Restriction of Ribbon Development Act empowered them to prescribe, with the approval of the Minister of Transport, standard widths ranging from 60 feet to 160 feet, and greater than 160 feet where an excess over that dimension is necessary in order to provide space for the slopes of embankments or cuttings.

It must be admitted, however, that even the maximum permissible standard width of the Restriction of Ribbon Development Act (160 feet) compares unfavourably with the layout of roads on the parkway system, which has been adopted and is being extended in the United States. It is understood that in the case of many of these parkways access from buildings is prohibited and that their use is confined to private cars, with a speed-restriction of 35 miles per hour. There is nothing to prevent highway authorities from constructing parkways in Britain, but examples of lay-out on such lines are extremely rare. The American practice could with advantage be emulated, although it is doubtful whether in Great Britain public opinion would tolerate the exclusion of industrial vehicles from roads constructed and maintained at the public expense.

The summary in Table VII applies more particularly to new road construction than to the treatment of existing roads, which is dealt with in later paragraphs. It indicates the effective standard widths recommended by the Ministry of Transport as appropriate to the various layouts that are likely to be required for major traffic routes.

The eleven typical cross-sections shown in *Figs. 4* and *5* (pp. 76–77) illustrate some of these layouts, and certain intermediate ones which special local conditions may require, either in new construction or in widening and adapting existing roads.

Where the road is expected to carry heavy commercial and public-service vehicles in large numbers, and provision has to be made for turning space between the carriageways of a dual system, a minimum width of 66 feet is necessary between the outer curb-lines. In such cases the width for layout (*c*) in Table VII should be increased to 100 feet and that for layout (*d*) to 120 feet.

The British practice with regard to the width of the reservations separating double carriageways is well summed up in the Ministry's recommendation that this should be of the maximum width consistent with the general layout of the road. It is also customary to aim at

TABLE VII.

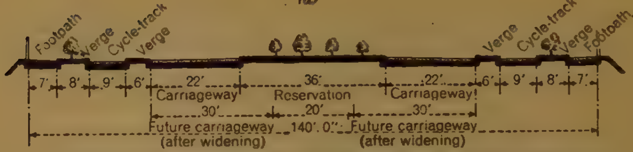
Reference.	Ultimate layout.	Corresponding minimum standard width (excluding earth-works): feet.
(*a*)	Single carriageway not exceeding 30 feet wide, with footpaths and verges	60
(*b*)	Single carriageway not exceeding 30 feet wide, with footpaths, cycle-tracks, and verges	80
(*c*)	Dual carriageways, each of two traffic-lanes, with foot-paths and verges but no cycle-tracks (*Figs. 5* (*b*)) .	80
(*d*)	Dual carriageways, each of two traffic-lanes, with foot-paths, verges, and cycle-tracks (*Figs. 4* (*d*)) . . .	100
(*e*)	Dual carriageways, each exceeding two traffic-lanes, with footpaths and verges but no cycle-tracks . .	100
(*f*)	Dual carriageways, each exceeding two traffic-lanes, with footpaths, cycle-tracks, and verges (*Figs. 4* (*c*))	120
(*g*)	Where more adequate provision is required, for example for a more spacious central reservation, wider marginal verges, greater space for underground services, facilities for equestrian traffic and/or improved visibility, in addition to twin cycle-tracks and foot-paths (*Figs. 4* (*a*))	140

providing a minimum distance of $\frac{1}{4}$ mile between the gaps in these reservations, although this is difficult to obtain, except in entirely new construction with stringent control of access from adjoining land on a corresponding basis of measurement.

Where economic considerations permit, a minimum effective width of 140 feet is most desirable for all roads in which, in addition to dual cycle-tracks and footpaths, provision has to be made for the possibility that the two-lane 22-foot carriageways may each ultimately have to be widened to a dimension of 30 feet, in order to accommodate three traffic-lanes. *Fig. 4* (*a*) shows a layout appropriate to such a case, with a central reservation initially 36 feet wide, which even the eventual widening of the carriage-ways to 30 feet would not reduce to less than 20 feet in width; this would enable even fairly large vehicles to cross from one carriageway to the other

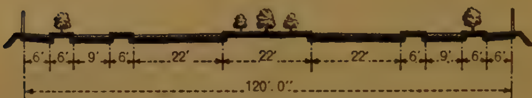
Figs. 4.

(a)



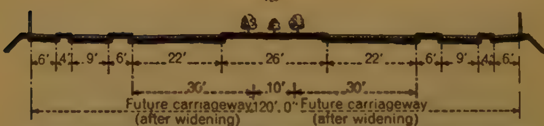
TWO TWO-LANE CARRIAGEWAYS, WITH SPACE FOR FUTURE ADDITION OF A THIRD LANE TO EACH.

(b)



TWO TWO-LANE CARRIAGEWAYS WHERE ADDITIONAL LANES ARE NOT CONTEMPLATED.

(c)

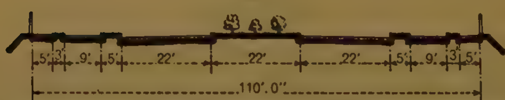


ALTERNATIVE TO *(a)*, WHERE CIRCUMSTANCES CALL FOR LESS GENEROUS PROVISION FOR AMENITIES WITHIN THE HIGHWAY.

(d)

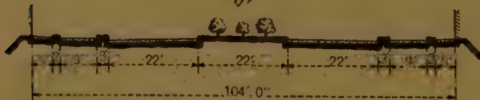
ALTERNATIVE TO *(b)*, WHERE CIRCUMSTANCES CALL FOR LESS GENEROUS PROVISION FOR AMENITIES WITHIN THE HIGHWAY.

(e)



ALTERNATIVE TO *(a)* AND *(c)*, WHERE COST OF HEAVY EARTHWORKS CALLS FOR REDUCED VERGE AND FOOTPATH WIDTHS.

(f)



ALTERNATIVE TO *(a)*, *(c)*, AND *(e)*, WHERE COST OF HEAVY BRIDGEWORKS CALLS FOR EVEN MORE REDUCED VERGE WIDTHS.

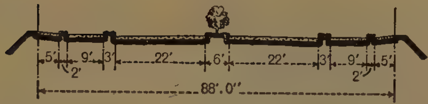
Scale: 1 inch = 48 feet.

Feet 10 5 0 10 20 30 40 feet

TYPICAL CROSS-SECTIONS FOR NEW MAIN TRAFFIC ROUTES.

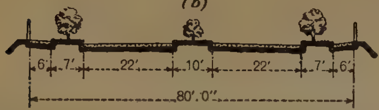
Figs. 5.

(a)



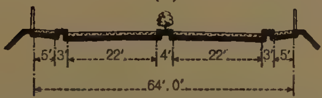
ALTERNATIVE TO FIGS. 4 *(b)* AND *(d)*, WHERE COST OF HEAVY BRIDGEWORKS CALLS FOR REDUCED VERGE WIDTHS.

(b)



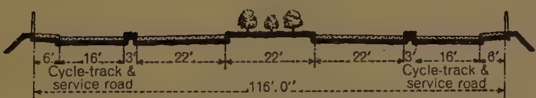
TWO TWO-LANE CARRIAGEWAYS, WITHOUT PROVISION FOR FUTURE WIDENING AND NO CYCLE-TRACKS.

(c)



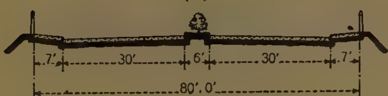
ALTERNATIVE TO *(b)*, WHERE COST OF HEAVY BRIDGEWORKS CALLS FOR REDUCED VERGE WIDTHS.

(d)



ADAPTATION OF EXISTING ROADS.
ALTERNATIVE TO FIGS. 4 *(a)* AND *(c)*, WHERE EXISTING FRONTAGE DEVELOPMENT PRECLUDES THE PROVISION OF SERVICE ROADS OUTSIDE THE HIGHWAY.

(e)



ADAPTATION OF EXISTING ROADS.
ALTERNATIVE TO *(b)*, WHERE EXISTING FRONTAGE DEVELOPMENT PRECLUDES THE PROVISION OF SERVICE ROADS OUTSIDE THE HIGHWAY.

Scale: 1 inch = 48 feet.
Feet 10 5 0 10 20 30 40 feet

TYPICAL CROSS-SECTIONS FOR NEW MAIN TRAFFIC ROUTES.

in safety. It is realized, however, that this layout does not represent perfection, in that the 36-foot reservation is likely to appear unduly wide when viewed in relationship to the outer verges. On the other hand, if ever in the future the 22-foot carriageways were widened to 30 feet, this central strip would be well in proportion to the remainder of the layout.

Similarly, for roads consisting of two carriageways each of two traffic-lanes (22 feet) in addition to dual cycle-tracks and footpaths, it is desirable, even though it may not always be practicable for reasons of economy, to provide a minimum effective width of 120 feet. *Fig. 4* (*b*) shows a suitable layout for this case, including a central reservation 22 feet wide, which gives a dimension of 66 feet between the outer curbs. *Figs. 4* (*c*) and (*d*) represent more cramped layouts alternative to those indicated in *Figs. 4* (*a*) and (*b*) respectively, but providing the same widths of paved surface.

In designing the layout for a new section of road passing through difficult country where abnormally heavy earthworks are to be expected, it is sometimes expedient as a means of effecting economy, but not without the sacrifice of some amenity, to reduce to the minimum the widths of all grass verges and reservations, while retaining the paved areas at their normal widths. If the necessity for this arises a road of 120 feet effective width under normal conditions can be reduced to an effective width of 110 feet, or even to 104 feet, as shown in *Figs. 4* (*e*) and (*f*).

Further, on account of the relatively high cost of bridge-works in connexion with new road construction, which may amount to as much as £30,000 per mile, where, in addition to railways and rivers, all subsidiary roads are bridged, it is not an uncommon practice as a measure of economy to reduce the effective road widths at the larger and more expensive bridges on the route. *Figs. 4* (*f*) and *5* (*a*) illustrate this principle applied to roads whose normal effective widths would be 120 feet and 100 feet respectively, the net saving of width being 16 feet in the former case and 12 feet in the latter. By carefully designing the layout so as to avoid abrupt changes in the transverse profile, it is possible to effect these restrictions of width at the principal bridges without prejudice to the appearance or safety of the road.

In the treatment of existing roads the influence of local conditions precludes rigid standardization of layout, but this does not prevent the application of such standard widths as may be appropriate to the circumstances. The first case to consider is that of roads passing through open country, where the paramount consideration is the maximum possible preservation of existing roadside amenities, such as trees and hedgerows, which are such a cherished feature of the English countryside. This can often be done by careful alignment, or by increasing the width of the central reservation or side verges to such an extent as may be necessary to permit the retention therein of these features.

In the absence of political or social influences of such a character as to hinder the normal course of road development in Great Britain, the next

Fig. 6.

TWIN CARRIAGEWAYS ON TRUNK ROAD IN WARWICKSHIRE.

Fig. 19.

FORMBY BY-PASS ON A CLASS I ROAD IN LANCASHIRE.

decade should see a considerable mileage of existing through routes treated in the manner just described. *Fig. 6* * illustrates a completed example on a trunk road in the beautiful midland county of Warwickshire. In this case it was possible to obtain the desired result without forming a central reservation of abnormal width.

The typical cross-sections shown in *Figs. 4* and in *Figs. 5* (*a*) to (*c*), and the remarks thereon, are all based on the assumption that the dual carriageways will be reserved primarily for the passage of through traffic, standing vehicles and purely local traffic being provided for outside the standard widths on the separate road systems, whether service roads or otherwise, which are provided to meet the needs of buildings erected on the adjoining land. In the case of new main traffic routes this can be achieved without much difficulty by the rigid control of access under the provisions of the Restriction of Ribbon Development Act. The present normal requirement is that means of access, whether from private property or from subsidiary roads, shall be confined to not more than one in every ¼ mile on each side of the road.

If the provisions of the 1935 Act are properly used, the traffic route of the future, as distinct from the ordinary shopping street or residential road, can be visualized as freed from the danger and obstruction occasioned by the presence of standing vehicles or by the sudden emergence of other road users from carriage drives, or from unduly frequent junctions with by-roads.

Provision for Standing Traffic.

The cross-sections shown in *Figs. 5* (*d*) and (*e*) (p. 77) are applicable to quite a different state of affairs. They constitute the second example (the first of which, relating to existing roads in rural areas, was discussed above) of how the adoption of standard widths for existing roads may be so affected by local conditions as to necessitate a special layout to meet the circumstances of the case.

It not infrequently happens that a section of an important road passes through an area which has been subject to intermittent frontage development in the form of residential and other property, so spaced longitudinally and transversely that the expense of the demolition of property necessary to secure the full normal highway width (in addition to that required for service roads) rules such a scheme out of consideration. Further, it may be that on the ground of expense, or for some other reason, the construction of a by-pass is not regarded as a practicable solution of the problem. The obvious remedy is to compromise in the matter of width, and in the means to be adopted for providing space for stationary and local traffic. This can be done either by combining the cycle-tracks and service roads, as shown in *Fig. 5* (*d*), or by providing one traffic-lane on

* From a photograph kindly lent by Mr. D. H. Brown, M. Inst. C.E., County Surveyor of Warwickshire.

each of the main carriageways for the use of cyclists and standing traffic, in addition to the lanes required for through traffic, as shown in *Fig. 5* (*e*).

Where provision for standing vehicles and for traffic serving the needs of local development has to be made by means of service roads running parallel to, and outside, the standard width of the main through route, these roads are not normally regarded as being the responsibility of the highway authority, and that authority does not, save in exceptional circumstances, take them over as part of the main route, but following construction to an approved specification they may be taken over as public highways subsidiary to the main route. In such cases the service road is laid out to a minimum width of 25 feet wherever possible, comprising a 16-foot carriageway separated by a 5-foot footpath from the boundary line of the individual plots or properties which it serves, and by a 4-foot verge from the main-road boundary.

The placing of service roads alongside the public highway is an orthodox and permissible device where the frontage is to be developed as a shopping area. This is unnecessary, however, where the adjacent land is to be developed for residential purposes, since in that case there is normally nothing to prevent the alternative arrangement of providing for the construction of estate roads parallel to, and at one building-plot depth from, the public highway.

Amenities.

Although the efforts of highway authorities are primarily directed towards making the road system adequate from a utilitarian aspect, the importance is fully realized not merely of safeguarding the charm and beauty of the country through which the roads pass, but also, wherever possible, of adding to existing amenities.

Parliament has shown its desire to encourage the preservation of roadside amenity by several legislative provisions. Section 12 of the Town and Country Planning Act, 1932, stipulates that the responsible authority may regulate the design and external appearance of new buildings in an area dealt with under a town-planning scheme, while Section 47 of the same Act provides powers for the removal of disfiguring advertisements. Section 7 (2) of the Restriction of Ribbon Development Act requires highway authorities to have regard to the need for preserving the amenities of the locality and for securing well-planned development.

Further, the control of access under Sections 1 and 2 of the last-mentioned Act encourages, and in the last resort compels, the developer to think in terms of group development and to prepare plans, often in co-operation with both the highway and the planning authority, which are free from the uneconomic and monotonous features associated with ribbon-building. It thus frequently happens that, while control of access is primarily designed to preserve the traffic value of the highway, it also exercises an indirect but positive influence on planning beyond the high

way boundary, quite apart from the direct control over the erection of buildings within 220 feet of the middle of the road.

Road Junctions and Intersections.

It has been shown in Table IV (p. 68) that 31·7 per cent. of all the fatal accidents, and 41·7 per cent. of the non-fatal accidents, recorded during the year 1936–37 took place at road junctions, which are naturally more numerous in urban than in rural areas. For this and other reasons it is only to be expected that the percentage of accidents would be higher in the former than in the latter case, and this is reflected in the Table. It is a fact, however, that owing to the high ratio of total road-mileage to area, junctions occur at very frequent intervals on British roads generally, and it has been estimated that under average conditions any new road constructed in Great Britain is likely to intercept an existing road not less than about once in every ½ mile.

The abolition of the dangers inherent in the orthodox but now obsolete "cross-roads" type of junction, in which two roads cross one another at the same level (often with inadequate cross-visibility), thereby permitting direct "cuts" between the intersecting streams of fast-moving traffic, may be brought about in a variety of ways; the relative traffic value of the two roads, coupled with economic considerations, will determine which method should be adopted in any particular situation.

If it were possible in new construction to arrange for all conflicting streams of traffic to cross one another at different levels by constructing junctions of the "flyover" type at every road intersection, something approaching 100-per-cent. safety at intersections would be assured so far as safety is dependent upon road design, but this is a counsel of perfection, which is unattainable for reasons that are referred to later.

It seems unnecessary and unprofitable to discuss at length the design of flyover junctions, since they are a well-established feature of American practice, whereas relatively few have yet been constructed in Great Britain. The traffic efficiency of a flyover bridge is at its maximum, and its economic justification greatest, when there is no necessity to provide inter-connexion between the two roads, and when there is no complication of design occasioned by the need for making separate provision for vehicles, pedal-cyclists, and pedestrians. These conditions exist on the German *Autobahnen*, and also apparently to a great extent outside the built-up areas in America, but they do not apply in Great Britain. This is the crux of the difference between the traffic and road conditions in the two latter countries, and it explains why flyovers have not yet been so universally adopted in England as on the American continent. Nevertheless, provision is being made on important routes for many flyover bridges, and for some flyover junctions, several of which are in course of construction.

Fig. 7, Plate 1, shows a recently-prepared design of a cloverleaf flyover junction intended for use at the intersection of two major traffic routes,

each containing two carriageways, two cycle-tracks, and two footpaths. It will be observed that cyclists and pedestrians are completely safeguarded from collision with vehicular traffic. The predominant factor in this design is the gradient adopted for the cycle-track approaches to the bridge, since for any predetermined headroom this gradient establishes the positions of the subways, which, in turn, control the lengths of the embankments and the arrangement of the switch-roads. A gradient of 1 in 15 has been selected, in the belief that most cyclists would prefer to negotiate a short rise of 1 in 15 to a longer one of, say, 1 in 20 or 1 in 24. An area of about 24 acres of land is required for this layout, and its cost in excess of the normal (as described on p. 85) is estimated in round figures at £80,000.

The alternative is to design junctions so that traffic streams converging and diverging at the same level will " weave " with one another, instead of making dangerous cuts, the layout being so arranged as to enable drivers readily to identify the paths they desire to follow. This is the underlying principle of the roundabout, which is essentially intended for situations in which two important roads carrying equal or nearly equal volumes of traffic intersect, or form either a forked or right-angled junction. Where space permits, it is equally suitable for the improvement of multiple crossings formed by the intersection of more than two important traffic routes.

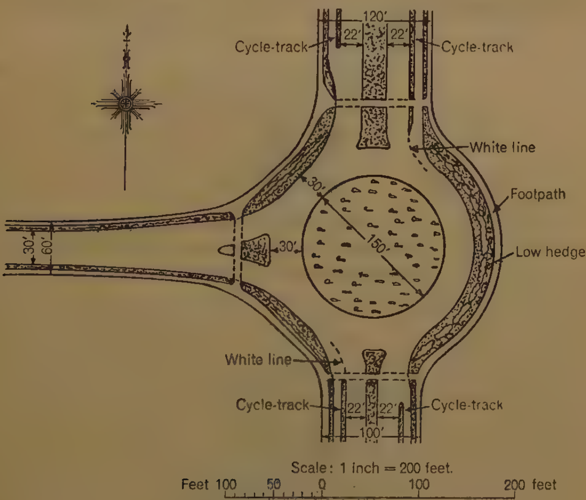
When dealing with an existing forked junction, experience shows that the best layout is obtained by placing the roundabout in the angle formed between the centre-lines of the two converging carriageways, the distance back from the point of their intersection varying according to the angle of intersection. If that angle is little short of 90 degrees the displacement would be trifling, whereas if it is 45 degrees or less it would be considerable; so also would the lengths of the existing roads to be diverted. The displacement should be sufficient to enable the cardinal principle of roundabout design to be observed, namely, the provision of sufficient length between the entrances to the circular carriageway from each of the converging carriageways to ensure that the manœuvre of weaving can be effected with safety by all vehicles moving at a speed as nearly uniform as possible. This length depends on the number of traffic-lanes to be connected with the roundabout, but 100 feet is usually regarded as the minimum for efficient working. In order to conform with this principle, it is desirable that the roads converging on the roundabout should enter it radially at equal angles, which will ensure uniformity in the speed of circulation. This is not, however, an essential condition, because a sufficient increase in the size of the central island will provide adequate weaving space, even though the angles of intersection may not be equalized.

Fig. 8 is an example of a roundabout which provides adequate weaving length without equalization of the angles of intersection, and fulfils all the requirements of the traffic using the north and south twin-carriageway road. Where the design is open to criticism is that south-bound traffic

from the westerly road, as well as west-bound traffic from the north, is forced to circulate for an unnecessary distance owing to the length of the carriageway on the eastern side of the roundabout, but as the westerly road is clearly the least important of the three, this is not a point of vital consequence.

The siting of a large roundabout on a twin-carriageway road in such a position as to provide perfection of design may be an extremely expensive operation, especially where it involves the diversion of an existing major road, and in all such cases traffic and economic considerations need to be

Fig. 8.

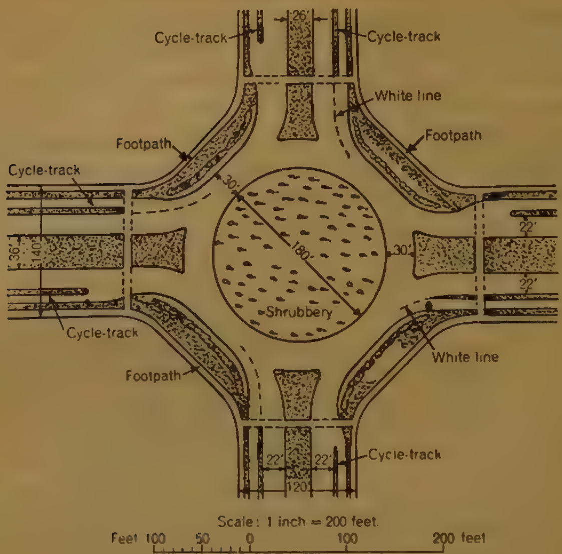


THREE-WAY ROUNDABOUT.

carefully balanced against one another. On the arterial roads in the vicinity of London and of most large centres of population, roundabouts conforming with the orthodox design shown in *Fig. 9* (p. 84), and having central islands ranging from 120 to 180 feet in diameter, are now commonplace. For new twin-carriageway roads the present standard practice is to provide a diameter of from 150 to 180 feet for the central island. *Fig. 10* (p. 84) illustrates a four-way roundabout which, by providing partial segregation, gives a greater measure of safety for cyclists.

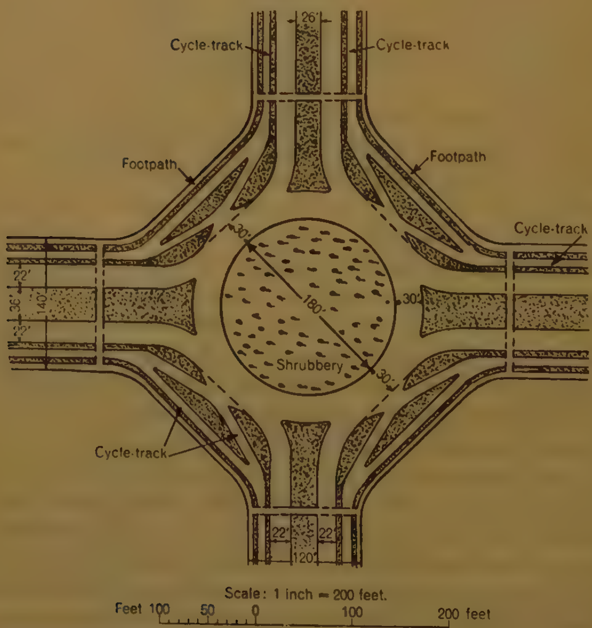
In built-up areas, roundabouts having central islands as small as 50 feet in diameter have served their purpose in slowing down traffic very considerably and reducing the severity of accidents, but it is obvious that roundabouts of such small dimensions must fail in their main purpose, which is to eliminate traffic cuts. In order to protect drivers from the dazzle of headlights, the central islands of roundabouts are usually banked up to a height of from 4 to 6 feet, and/or are planted with shrubs.

Fig. 9.



Four-way Roundabout.

Fig. 10.



Four-way Roundabout with Improved Facilities for Cyclists.

Whilst roundabouts on fast-traffic routes are admittedly sometimes a source of irritation to motorists in a hurry, it is unquestionable that they are well suited to British conditions, where there is so much turning and cross-traffic to be provided for, and they are never likely to be altogether discredited by the claims of junctions of the flyover type. Therefore, the ideal which the arterial roads of the future may be expected to produce is probably a judicious combination of roundabouts and flyovers, the numbers of each type on any particular road being determined by the relative claims of traffic and economic considerations.

It will be observed that in the roundabouts illustrated in *Figs. 8–10*, complete separate provision is not made for pedal-cyclists, and that for pedestrians merely the ordinary carriageway crossings are shown just short of the commencement of the gyratory system. The drawback associated with the common use of the circular carriageway by both vehicles and pedal-cycles is offset to some extent, however, by the enforced reduction in the speed of the traffic while performing the gyratory movement.

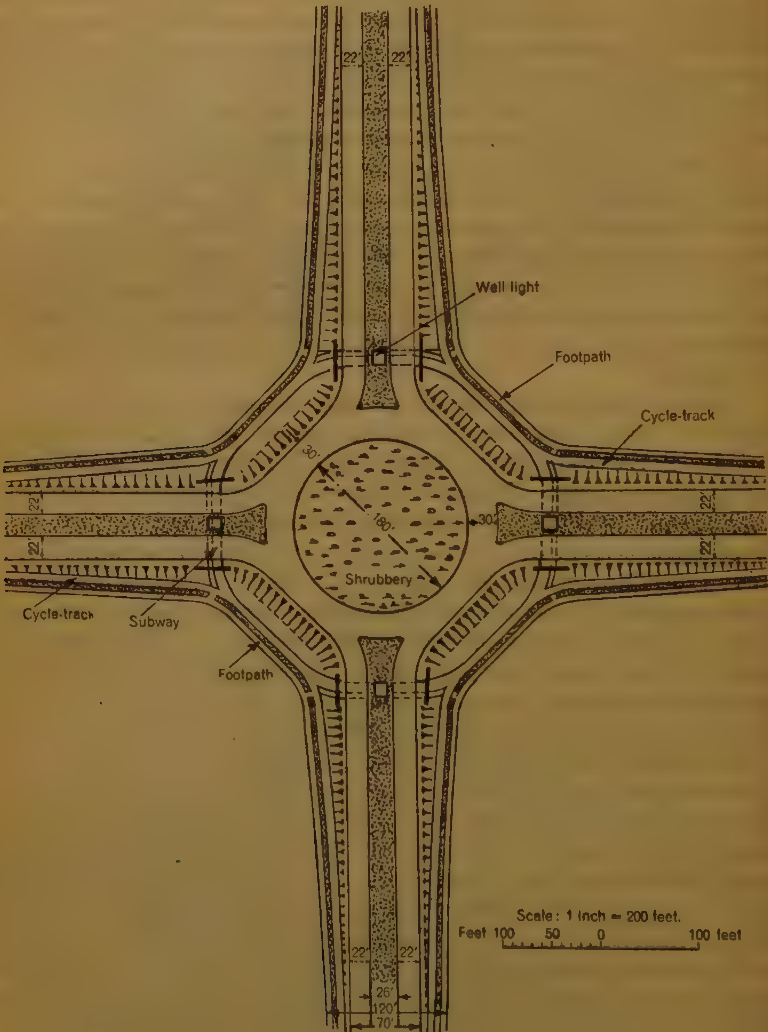
A means of providing a greater measure of safety for pedestrians, which is justified where the flow of vehicular traffic is continuous over long periods, is the installation of pedestrian-operated light-signals at the carriageway crossings. Where the amount of traffic justifies the additional cost, segregation of the cycle-traffic can be obtained, and complete safety for pedestrians assured, by constructing over-bridges or subways, but the heavy expenditure which this elaboration of the design entails has up to the present retarded development on these lines. It is important that, so far as practicable, all approaches to pedestrian subways and bridges should consist of easy ramps and not flights of steps, which involve so much additional effort that the average pedestrian will not take the trouble to use them unless circumstances force him to do so.

One of the latest types of roundabout, which is elevated, with ramped approach-roads, and includes subways for both cyclists and pedestrians, is illustrated in *Fig. 11* (p. 86). It has the merit of providing the maximum safety at the minimum expenditure. The subways are short and are lighted by means of wells through the reservations between the carriageways. An approximate estimate of the cost of this roundabout in excess of the normal (that is, the cost of one road having a layout as in *Figs. 4* (*c*) (p. 76), carried straight through, and of the other road as far as the boundaries of the first) including the acquisition of land, would be about £15,000. The alternative to this design, which would be adopted where the local conditions are such as to make it the more economical arrangement, is to place the roundabout at the lower level and to bridge the cycle-tracks and footpaths over the approaches thereto.

The next type of junction to be considered is that in which one of the intersecting roads is definitely of inferior traffic importance to the other, in which circumstances neither the interruption of the flow of traffic on

the major route by the interposition of a roundabout, nor the cost of its construction, can be justified. In a fair proportion of such cases, especially

Fig. 11.



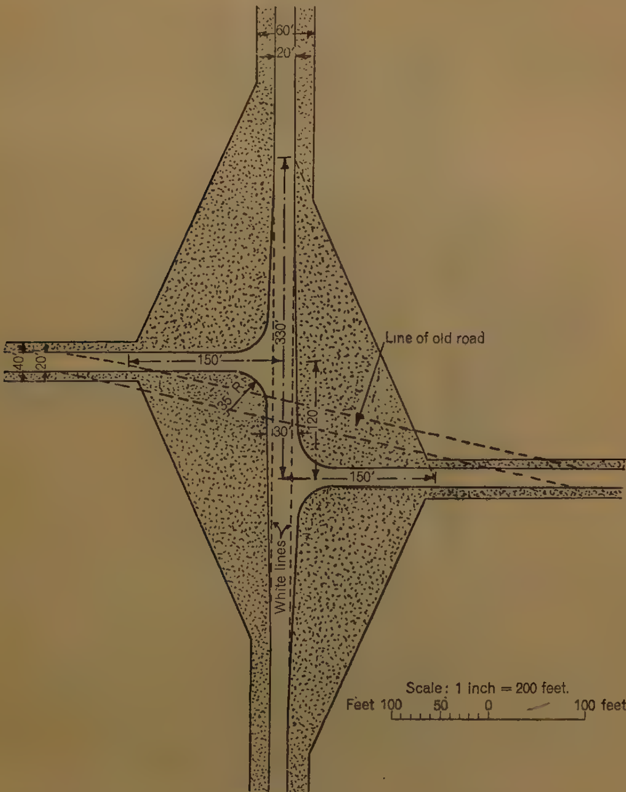
ELEVATED ROUNDABOUT, WITH SUBWAYS FOR CYCLISTS AND PEDESTRIANS.

where the minor road carries a relatively small volume of traffic, the erection on that road of "SLOW" signs, or, where visibility is bad, of "HALT" signs, which give definite priority of movement to traffic on the major road, with severe penalties for their contravention, has been found

to be an effective remedy. Where more drastic measures are called for, on account of the volume of traffic and the speed of vehicles approaching the cross-roads from the minor road, a device that may be adopted with advantage, as an alternative to constructing a bridge, is to convert the cross-roads into a "stagger."

The relative merits on traffic grounds of left-hand versus right-hand

Fig. 12.

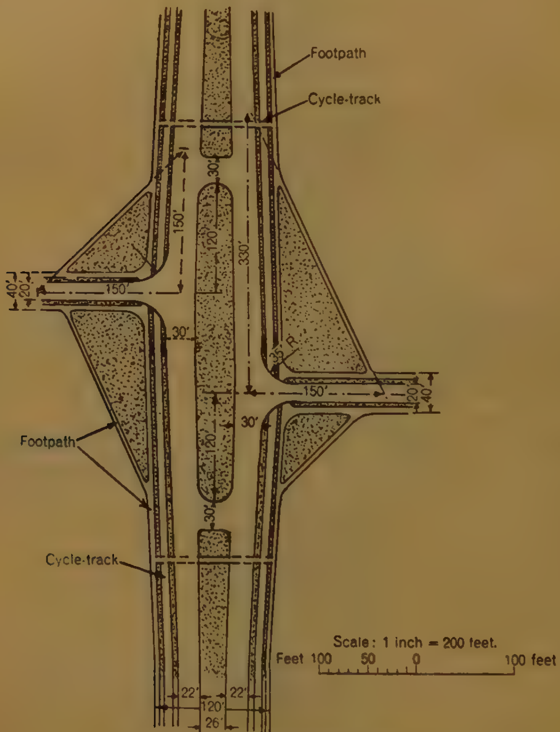


Right-hand Staggered Junction.

staggers have for some years been a vexed question amongst highway engineers, and although large numbers of the former have been constructed, the experience of the last few years has shown that from the safety point of view the latter is the better design, particularly where the major road contains a twin carriageway carrying a considerable volume of fast-moving traffic. *Fig. 12* shows in its simplest form a right-hand stagger between two single-carriageway roads, which constitutes in effect the formation of two independent right-angled junctions separated

by the intervening section of the carriageway of the major road, having a minimum length of 120 feet and being suitably widened, in order to assist the weaving operation. It will be noted that the lines of sight are based on a stopping distance of 330 feet, which allows for a motor-vehicle which is being driven at 60 miles per hour to travel 90 feet before the driver applies his brakes, after which, assuming a braking efficiency of 50 per cent., it will be brought to rest within a further distance of 240 feet.

Fig. 13.

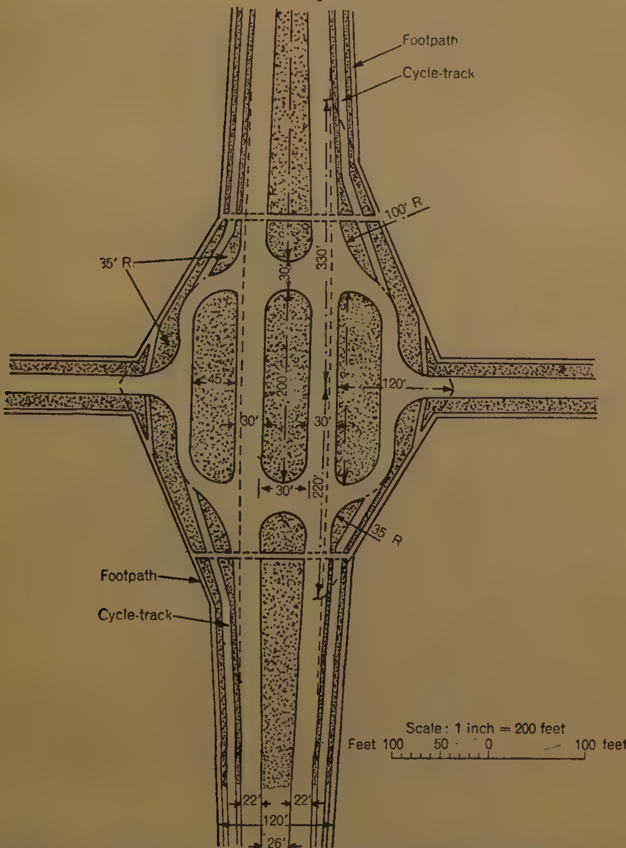


LEFT-HAND STAGGERED JUNCTION.

The theory underlying the left-hand staggered junction is similar to that of the roundabout, in that it puts vehicles emerging from the minor road to the necessity of weaving into the traffic on the major road before turning out into the continuation of the minor road on the other side. In actual practice, however, there is the important difference that whereas weaving takes place at a roundabout when traffic is necessarily moving slowly, there is at a staggered junction no limit to the speed at which the traffic on the major road may be travelling. For this reason weaving may be an extremely perilous, and under some conditions of traffic, an almost impossible, operation.

This point will be appreciated by reference to *Fig. 13*, which conforms with the Ministry's recommendation of January 1937 for a left-hand stagger on a twin-carriageway road. As such, this layout would be equally correct if the entrance to and exit from the major road were exactly opposite one another. Its conversion into a right-hand stagger may be effected by the simple expedient of moving the openings in the central reservation inwards

Fig. 14.



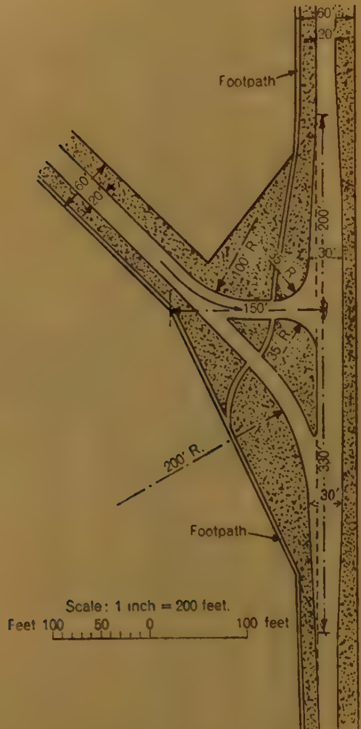
Double Baffled Junction on Twin-Carriageway Road.

om the positions shown until they are respectively opposite the centre-
nes of the two minor roads.

The modern equivalent of the design shown in *Fig. 13* consists in acing a baffle opposite each entrance from the minor road, and so intro-
ıcing a modified form of roundabout working, as illustrated in *Fig. 14.*
ne approximate estimated cost of this junction in excess of the normal (as
eviously described) is about £2,000. When a twin-carriageway road is

constructed, or the carriageway of an existing road duplicated, the adoption of this design avoids the necessity for staggering any cross-roads that may be met with. The desirability none the less remains of introducing modern layouts, well splayed for visibility purposes, at all acute-angled or Y-junctions between subsidiary roads and the major route, and this is done wherever local conditions permit.

Fig. 15.

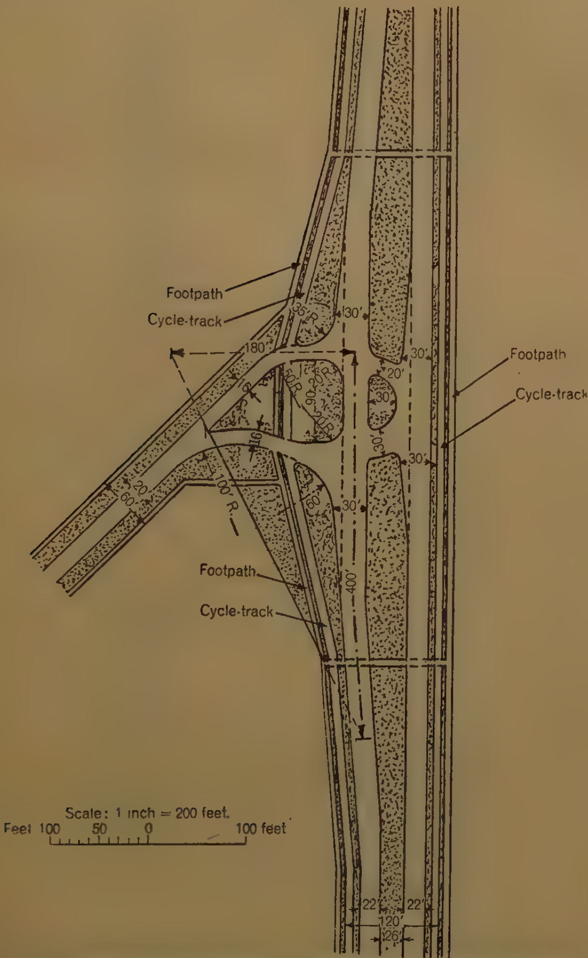


Improved Forked Junction.

This type of junction is dealt with by carrying out a diversion of the minor road, varying in length according to the angle of the existing intersection. *Figs. 15* and *16* illustrate how these diversions may be effected, in the first case where the major route is a single-carriageway road and in the second case where it has two carriageways. Both these designs embody the principle of introducing a check, in the form of a right-angled junction between the carriageway of the minor and that of the major road, thus enforcing a reduction in the speed of vehicles entering the latter, coupled with the provision of adequate visibility, and facilities for easy exit from the major to the minor road. The same principles underlie

the design of *Fig. 17* (p. 92), which illustrates a modern layout for the improvement of the junction between two single-carriageway roads meeting at right angles, without cycle-tracks.

Fig. 16.



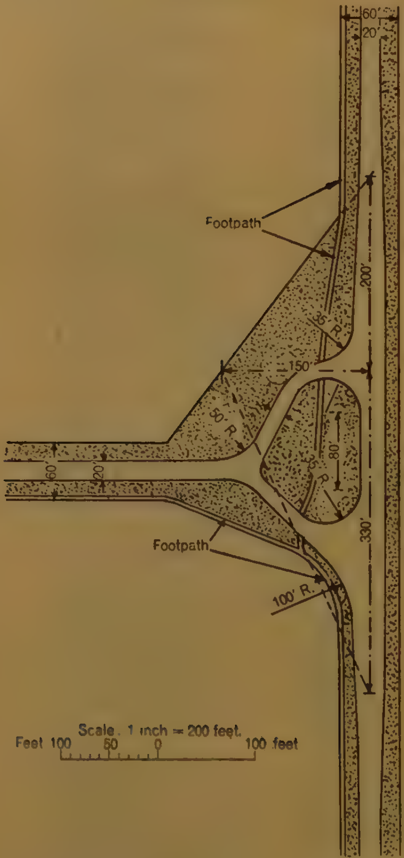
IMPROVED FORKED JUNCTION ON TWIN-CARRIAGEWAY ROAD.

Fig. 18 (p. 93) represents a baffled T-junction between a single-carriageway road and a major road which contains twin carriageways; this layout corresponds to that shown in *Fig. 14* (p. 89). Where traffic considerations warrant the expense, which is considerable, both these designs may be elaborated by the provision of subways to carry the foot-

paths and cycle-tracks under all the carriageways. In the case of the double baffled junction (*Fig. 14*), the additional cost of the subways would amount to about £7,000.

The circumstances in which automatic light-signals are justified

Fig. 17.



Improved Right-angled Junction.

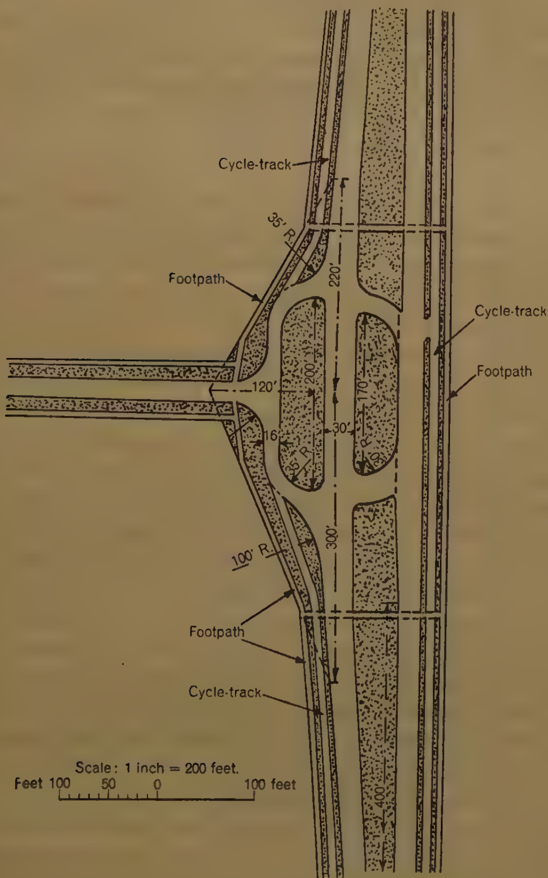
confines their use almost exclusively to built-up areas, with which this Paper is not primarily concerned. It is sufficient, therefore, to remark that they have proved to be of great value in regulating traffic at road junctions, and, in the great majority of cases, in minimizing the number and severity of accidents.

Horizontal and Vertical Alignment.

This all-important aspect of highway design calls for separate and quite

different treatment in its application to existing and to new roads respectively. In the former case local conditions are the prevailing factor, and although it is necessary to have some ruling guide, standardization may well be impossible. The general practice is to secure, so far as economically practicable in improvement works, a minimum radius of 1,000 feet (corre-

Fig. 18.



BAFFLED JUNCTION ON TWIN-CARRIAGEWAY ROAD.

ponding to a curve of about 6 degrees), and to aim at a maximum gradient f 1 in 30, but 1 in 20 is accepted as satisfactory in difficult country.

In the re-alignment of existing roads and the improvement of bends and bows, there is much scope for the use of transition-curves based on the mniscate, the spiral, or the cubic parabola, in conjunction with circular

curves where necessary. Within the limits of the deviation-angles employed in highway practice there is little difference between the results obtained in using either of the two former, but their relative advantages in design and in facility of setting out have for some years been a subject of controversy amongst engineers in Great Britain.

From the point of view of high-speed light traffic, it would be highly satisfactory if all such curves could be based uniformly on a design-speed of, say, 60 miles per hour, but the limitations imposed by the physical features associated with the existing alignment have led to the adoption (with successful results in the work so far accomplished) of design-speeds of from 30 to 60 miles per hour, varying according to the character of the road and the topography of the country through which it passes.

In this connexion the fact must be constantly borne in mind that even in open country certain classes of road vehicles are subjected to artificial speed-restrictions ranging from 5 to 30 miles per hour, and that the ordinary public highway has to form the permanent way alike for the 80-miles-an-hour sports car and the powerful traction-engine labouring along at 5 miles an hour with three trailers, as well as for the horsed farm-wagon with its top-heavy load of hay.

It is found that for new roads long straight stretches are undesirable, since they produce monotony and undue fatigue on the part of drivers. So far as practicable it is considered preferable to adopt sweeping curves of large radii (from 5,000 to 10,000 feet), but here again local conditions play an important part in preventing universal attainment of the ideal. In new construction and in the re-grading of existing roads, as, for example, at bridge-approaches, the practice is to introduce at all changes of gradient vertical parabolic curves, of sufficient length in the case of summit curves to ensure that a sight-line 500 feet long (measured 3 feet 9 inches above the carriageway) is obtained from any point on either approach; this is naturally of more vital importance in the case of single-carriageway roads than in the case of twin carriageways. A dimension of 200 feet is generally regarded as the minimum length for a vertical curve at a sag. The re-grading of a carriageway without diversion from existing alignment is not always economically justifiable or practicable.

A range of vision no less than that stated above is, of course, equally necessary on horizontal curves, and schemes for the improvement and re-alignment of existing through routes are designed on that basis.

Maintenance, Improvements, and New Road and Bridge Construction.

Maintenance (Methods and Materials).

The original structure of all British roads dating from before the motor-car era was compacted local material of some kind, such as flint or gravel, or waterbound " metalling ", consisting of broken stone of one of the

calcareous or igneous groups. This metalling has been found to range from 6 to 15 inches in thickness according to the nature of the subsoil, or alternatively it may be confined to a surface crust only, from 3 to 6 inches thick, supported by a Telford base.

Road maintenance originally consisted of patching and re-surfacing, both operations being carried out with waterbound material, and the effect of applying successive coatings over a period of many years can be seen to this day. The practice of building up the crown of the carriageway (partly for the purpose of facilitating drainage) to the neglect of the sides, is the cause of the excessive camber on many British roads, the removal of which has been engaging the attention of highway authorities for the past 20 years, and is still far from complete.

Hot surface dressing is carried out nowadays with tar and bitumen of various grades, the temperatures at which they are applied varying with the physical and chemical characteristics of the material. Considerable developments have taken place in the production of emulsified bitumens, and emulsions of tar are also used, but less extensively than bitumen emulsions. A method of re-surfacing now greatly in vogue consists in laying a thin coat of roller-finished bituminous sand carpeting, to which chippings may be added during mixing. It may range from ½ inch to about 1 inch in thickness, according to the nature of the base on which it is laid, the life demanded of it, and the intensity of the traffic to be carried. An essential for this surfacing is a solid well-shaped base, and the best results have been obtained where this is a tar-bound or bitumen-bound carriageway, as opposed to a waterbound road merely surface-dressed. The cost of thin surfacing varies from about 1*s.* 3*d.* to 2*s.* 10*d.* per square yard, according to its thickness and to other circumstances. A general average figure for the cost of ¾-inch work is about 1*s.* 10*d.* per square yard, contrasted with an average of about 4½*d.* per square yard for surface dressing with hot bitumen and ¾-inch granite chippings. With a traffic-density of up to about 10,000 tons per day, a life of at least 5 years may be counted on for a surface coat of this description.

The present general practice is for tar macadam, cold or semi-hot process, to be laid in two coats, but hot tar macadam is usually laid in a single coat of graded material. Most bituminous macadam is laid as two-coat work, three-coat work being exceptional. Sometimes a light application of sand or grit, pre-coated with a small percentage of binder, is brushed into the surface. This grit does not completely fill the interstices between the large aggregate, but it helps to seal the surfacing and so adds to its durability.

An average estimate of the cost of 3½-inch two-coat work with granite aggregate, exclusive of the cost of preparing the base, is about 4*s.* 0*d.* per square yard. The cost of bituminous macadam varies rather more than that of tar macadam owing to the many available types of natural and residual bitumen, and the numerous proprietary compounds into which

they are manufactured with mineral aggregates of various kinds, with or without the addition of tar, and each with its own claim for preference, but broadly speaking it is correct to state that there is little difference between the average costs of these two materials.

Other materials used for road surfacing are wood blocks, setts of granite or other stone, and concrete, each of which has its own appropriate use: for example, wood blocks (on a concrete base) are used for long life in main thoroughfares in large towns, and granite setts (on a concrete base) for heavily-trafficked dockland roads, whilst concrete in slab construction is pre-eminently the material favoured for the carriageways of new roads of modern design.

Apart from these, the most durable material in general use for road surfacing is natural or synthetic asphalt, laid hot, and with this material the greatest perfection of transverse and longitudinal profile is obtainable. Mastic and powdered rock asphalt are applied by screeding, trowelling, and ironing, with the addition of chippings as a precaution against slipperiness. Such materials are finally consolidated by the use of medium and lightweight rollers respectively.

The composition and manufacture of asphalt and the methods of its use for road surfacing are regulated by a number of specifications issued by the British Standards Institution[1], compliance with which is recommended by the Ministry.

Improvements.

Alignment and improvement when viewed in relation to existing roads are interdependent questions. Improvement in width on British roads more often than not involves also improvement in alignment, subject to the limitations imposed by the factors that have been mentioned. It is merely a question of degree whether a re-alignment is sufficiently extensive to be regarded as a complete diversion, to which the higher standards of new construction can be applied.

A vast amount of road-widening and re-alignment has been carried out during the past 20 years. The principal improvements effected within existing alignments consist in the opening out of lines of sight, the modernization of junctions, the removal of excessive camber, and the superelevation of bends. The principal difficulty in applying scientific methods to the treatment of bends on existing roads without re-alignment is that in many cases these bends consist of compound curves. It is not uncommon to find that a bend is made up of three or four curves of differing radii, sometimes with intervening short sections of straight, also of variable length.

There has been much criticism of the lack of banking on British roads,

[1] Obtainable from the Publications Department of the British Standards Institution, London.

but the superelevation of bends was quite unknown at the time of their construction. Nevertheless, although the formation of banking is an expensive operation by comparison with ordinary re-surfacing, the general safety of the roads has been greatly enhanced in recent years by the superelevation of bends, frequently by methods of compromise and adjustment necessitated by existing conditions, from which a departure could not be made. The Ministry's recommendation is that superelevation should be applied wherever practicable in carrying out improvement works of any kind in relation to roads on their existing alignment, subject always to consideration of the question of whether, in the case of small-radius bends, a complete diversion is not a preferable alternative.

New Road Construction.

The scope of this Paper does not permit an exhaustive discourse to be made on constructional methods, but the following are a few of the salient features of present-day practice.

Concrete cast in situ in the form of slabs is well established as the standard method of construction for new carriageways. Mechanical plant for placing, tamping, and finishing the concrete is now being used, and will be employed more extensively in the future. It is doubtful, however, whether machine-tamping effects any economy by comparison with ordinary hand-tamping, which has hitherto been the normal procedure. In the construction of a by-pass completed in 1939 comparisons were made between mechanically- and manually-tamped and finished work. There is evidence that the riding qualities of the machine-finished work are better, except at the joints, where a different technique is required, but there has been no saving in cost by comparison with the hand-finished work.

The question of the value of reinforcement has been studied for some years, and the following conclusions may be of interest. Under very favourable conditions unreinforced concrete may not crack, but usually it does. The cracks soon extend over the full width of the slab and open sufficiently to be conspicuous, so that they tend to spall, and if not sealed may let water into the foundation. Reinforcement in the small quantities normally used in road slabs does not entirely obviate cracking, but it tends to reduce it. The cracks are generally quite short, however, and do not extend appreciably, even after several years. Moreover, in most cases they remain thin, so that with few exceptions sealing is not necessary. Some years ago cracking at the corners of slabs was of fairly frequent occurrence, but in contemporary practice this has been obviated by the introduction of rods of the hairpin type. It is safe to assume that the omission of reinforcement would cheapen and facilitate the construction of machine-finished concrete, and greater care in the preparation and consolidation of foundations, coupled with the drier mixes and better compaction made possible by machine-finished work, may reduce the risk of cracking in unreinforced slabs; but the conclusions recorded above, which are the result of experi-

ence on many experimental and non-experimental works, indicate that the use of reinforcement is at present justified.

It is usual on straight sections of twin-carriageway roads to construct the carriageways with a uniform cross-fall outwards from the centre of the road. A slope of 1 in 48 is generally adopted, with a rise of ¼ inch in the centre of the carriageway as a safeguard against the formation of hollows through constructional faults. Curvature is, of course, designed in accordance with the transition-theory now generally accepted for highways, and the amount of superelevation is graduated so that, commencing from zero at the tangent points, it attains its maximum at the end of the transition-curve, remaining uniform throughout the circular curve (if any).

Some highway engineers are advocating that raised curbing should be dispensed with in all cases where there is not a footpath immediately adjacent to the carriageway, and from the amenity point of view this arrangement is definitely advantageous. There is no question, however, that a raised curb is of great assistance in night driving, and even more so in foggy weather and in snow. In order to assist visibility curbs are frequently whitened, and painted in alternate bands of black and white at junctions and roundabouts.

The principal objection to the use of sunk curbs or abutments alongside raised grass verges is that the accumulation of refuse from the carriageway and (in some cases) of earth resulting from the trimming or wearing away of the vertical faces of the verges, makes it impracticable to keep the abutments clean and contrasting sharply in colour with that of the carriageway, and in such circumstances the extra cost of their construction is not readily justified.

The practice of forming the verges flush with the carriageway has certain advantages, one being that it lessens the expense of constructing surface-water drainage, but if the road includes cycle-tracks and footpaths as well as dual carriageways, the problem remains of disposing of the surface water from the carriageways without allowing it to overflow on to the cycle-tracks and footpaths.

Cycle-tracks and footpaths are usually constructed either of concrete cast in situ from 3 inches to 4½ inches thick, or of two-coat tar macadam, up to 3 inches thick. The cost of the cycle-tracks which have been constructed up to the present has varied considerably, but from 4*s*. 0*d*. to 5*s*. 0*d*. per square yard for concrete tracks 4½ inches thick may be regarded as a fair average.

Good typical examples of modern British practice in new-road construction are afforded by two recently completed by-passes on Class I roads, one being in Surrey and the other in Lancashire. A view of the latter is given in *Fig. 19* (facing p. 79).

Bridges.

By the provisions of Section 2 of the Road Traffic Act, 1930, mechanically-propelled road vehicles were divided into various classes according to their weight, use, etc., and by the same section the Minister of Transport was given power to make regulations (1) sub-dividing any such class according to weight, construction, nature of tires, use, or otherwise, and (2) varying the maximum or minimum weights applicable to any class according to Section 2 of the Act.

The general effect of the Act itself, and of the numerous regulations subsequently made thereunder, which have an important bearing on bridge design, can be conveniently indicated in tabular form. Table VIII (p. 100) shows the present statutory classification of vehicles according to their unladen weight and use, and Table IX (p. 101) shows the maximum permissible laden weight appertaining to each class, together with legal requirements as to the distribution of weight. The maximum limits of overall length, width, and overhang are also governed by regulations made by the Minister under the same Act.

Fig. 20, Plate 1, shows the standard load for highway bridges and the equivalent loading curve based on the Ministry of Transport standard train. This is the minimum loading recognized by the Department for highway-bridge construction, reconstruction, or strengthening works assisted by grant from the Road Fund. Allowance for impact is included, and therefore need not be considered separately.

For structural steel the stresses set out in Specification No. 153, Part 3 (1933) of the British Standards Institution are approved by the Department for bridge-design, and the maximum permissible stress for steel reinforcement used in bridges is fixed at 16,000 lb. per square inch.

The maximum working stresses in concrete recognized by the Ministry are given in Table X (p. 102). These stresses relate to concrete made from all approved grades of Portland cement of British manufacture, provided that (1) the cement complies with the current B.S.I. specification for Portland cement, (2) crushing tests of 6-inch cubes made with concrete taken from the mixer during progress of the work show consistently the results listed in the Table, and (3) the cement is weighed, and not measured by volume. It is recommended that whole bags be used to the batch so that weighing on the works becomes unnecessary.

It is understood that in the United States a headroom of 14 feet is permitted under highway bridges. In view, however, of the greater height of the vehicles which use British roads, the Ministry of Transport's requirement is that a minimum headroom of 16 feet 6 inches over carriageways should normally be provided.

There has been considerable activity in bridge-construction since the great war of 1914–18, and during the past 10 years nearly five thousand highway bridges have been constructed or widened in Great Britain,

Table VIII.—Classification of Vehicles.

- Mechanically-propelled for use on roads (motor-vehicle). [R.T.A. 1930, Sec. 1.]
  - Not constructed to carry passengers, or a load, other than fuel and equipment.
    - Heavy locomotive.
      - Unladen weight exceeding $11\frac{1}{2}$ tons. [R.T.A. 1930, Sec. 2 (1) (a).] Maximum $15\frac{1}{2}$ tons, or $17\frac{1}{2}$ if with elastic tires. [S.R.O. 1937, No. 229.*]
    - Light locomotive.
      - Unladen weight from $7\frac{1}{4}$ tons to $11\frac{1}{2}$ tons. [R.T.A. 1930, Sec. 2 (1) (b).]
    - Motor-tractor.
      - Unladen weight not exceeding $7\frac{1}{4}$ tons. [R.T.A. 1930, Sec. 2 (1) (c).]
  - Specially authorized, e.g. track-laying vehicle. [R.T.A. 1930, Sec. 3 (1) (b).]
  - Constructed to carry a load or passengers.
    - Heavy motor-car.
      - Unladen weight exceeding $2\frac{1}{2}$ tons. [R.T.A. 1930, Sec. 2 (1) (d).]
    - Motor-car.
      - If constructed to carry not more than seven passengers and fitted with pneumatic tires, unladen weight not exceeding 3 tons. [R.T.A. 1930, Sec. 2 (1) (e) (i).]
      - In any other case, unladen weight not exceeding $2\frac{1}{2}$ tons. [R.T.A. 1930, Sec. 2 (1) (e) (ii).]
    - Motor-cycle.
      - Less than four wheels. Unladen weight not exceeding 8 cwt. [R.T.A. 1930, Sec. 2 (1) (f).]
    - Invalid carriage.
      - Specially designed and constructed. Unladen weight not exceeding 5 cwt. [R.T.A. 1930, Sec. 2 (1) (g).]
- Drawn by a motor-vehicle (trailer). [R.T.A. 1930, Sec. 1.]

* This denotes the Motor Vehicles (Construction and Use) Regulations, 1937, dated the 24th March, 1937, made by the Minister of Transport by virtue of the powers conferred on him by the Road Traffic Act, 1930.

TABLE IX.—MAXIMUM PERMISSIBLE LADEN WEIGHTS AND DISTRIBUTION, ETC.

Type of vehicle.	Legal limits of weight.	Distribution of weight and other requirements.
Locomotive.	Not to exceed unladen weight by more than 3 tons.	Not more than three-quarters of total weight to be carried by any two wheels, subject to certain exceptions in favour of vehicles which do not normally use public roads, except for passing between sites on which they are to be used.
Motor-car and heavy motor-car with four wheels. Heavy motor-car with six wheels. Heavy motor-car with more than six wheels.	Not to exceed 12 tons. Not to exceed 19 tons. Not to exceed 22 tons.	Must be equipped with pneumatic tires, subject to exceptions in favour of certain specified units, such as cleansing vehicles. Wheel-load not to exceed 4 tons, where no other wheel lies in the same transverse line. Load on two-wheeled axle not to exceed 8 tons.
Heavy motor-car with four wheels, propelled by steam. Heavy motor-car with six wheels, propelled by steam.	Not to exceed 14 tons. Not to exceed 20 tons.	Not to be driven at speed exceeding 12 miles per hour when not provided with pneumatic tires, and total loads are in excess of 12 tons and 19 tons respectively. Load on two-wheeled axle not to exceed 9 tons.
Public-service vehicle, single deck, with four wheels. Public-service vehicle, double deck, with four wheels. Public-service vehicle, single or double deck, with more than four wheels.	Not to exceed 9 tons. Not to exceed $10\frac{1}{2}$ tons. Not to exceed $12\frac{1}{2}$ tons.	Load on two-wheeled axle not to exceed 6 tons for single-deck vehicle and 7 tons for double-deck vehicle.
Trailer drawn by locomotive. Trailer drawn by tractor or motor-car. Trailer drawn by steam motor-car.	Whole train not to exceed 40 tons. Whole train not to exceed 22 tons. Whole train not to exceed 24 tons.	Load on two-wheeled axle not to exceed $6\frac{1}{2}$ tons, except in following cases, for which limit is extended to 8 tons, provided that pneumatic tires are fitted: (*a*) two-wheeled trailer forming part of articulated vehicle having a total laden weight not exceeding 19 tons, and (*b*) four- or six-wheeled timber carriage with total laden weight for trailer not exceeding $19\frac{1}{2}$ tons, and subject to speed limit of 12 miles per hour.

GENERAL: Load on any strip of road 2 feet wide, extending transversely over width of vehicle, not to exceed 10 tons for any motor-car, heavy motor-car, or trailer. Further regulations have been made to apply to track-laying vehicles, and also to special vehicles used for transportation of heavy indivisible loads—for example, engineering plant—which vehicles are restricted to a maximum speed of 5 miles per hour.

TABLE X.—PERMISSIBLE WORKING STRESSES IN CONCRETE FOR BRIDGE-WORKS.

Concrete mix.			Working stress, f_c: lb. per square inch.	Modular ratio.	Crushing strength of concrete in 6-inch cubes: lb. per square inch.	
Cement: lb.	Fine aggregate: cubic feet.	Coarse aggregate: cubic feet.			At 28 days with ordinary Portland cement, at 7 days with rapid-hardening Portland cement.	Additional test (if required) as an indication. At 7 days with ordinary Portland cement, at 3 days with rapid-hardening Portland cement.
A	2	4	$5A+300$	—	$15A+900$	$10A+600$
90	2	4	750	15	2,250	1,500
120	2	4	900	15	2,700	1,800
150	2	4	1,050	12	3,150	2,100
180	2	4	1,200	10	3,600	2,400

mainly by local authorities with financial assistance from, and in consultation with, the Ministry of Transport.

New bridges are generally constructed either of reinforced concrete or of steel. This applies more particularly to long-span structures, but brick, stone, and sometimes a combination of these materials, are commonly used with pleasing effect for bridges having one or more relatively short spans.

The largest reinforced-concrete arch-bridge in Great Britain is that completed a few years ago to carry the Great North road over the river Tweed at Berwick. This bridge carries a roadway rising from one side of the crossing to the other on a series of arches of increasing span, the maximum being 361 feet. The total length of the bridge is 1,405 feet and it has a width of 46 feet. The parapet is of dressed stone.

In nearly every case where a bridge has been strengthened, it has also been necessary to widen it, and to a rather less extent the converse of this is true. Ancient masonry or brick arch-bridges have most commonly been widened by taking down one face and re-erecting it on the new line, using the existing materials as far as possible, the extensions of the arch vaults being constructed in reinforced concrete with the surface left comparatively rough, so as not to contrast too sharply with the appearance of the original structure.

Abingdon bridge over the river Thames and an adjacent mill stream in Berkshire is an example of an ancient many-arched structure (built in 1416, with the addition of flood arches some years later), which was successfully reconstructed about 12 years ago by substituting a modern 60-foot span for four of the original masonry arches. This work, together with the rebuilding of the flood arches, was carried out in reinforced concrete, faced with local stone obtained from the demolished structure. The bridge to-day consists of twelve arches, including the new navigation-span.

A rather different type of reconstruction is exemplified by the beautiful eighteenth-century English bridge over the river Severn at Shrewsbury, which was taken down a few years ago and re-erected to a greater width (50 feet), while at the same time preserving its original architectural features by using in the elevation stone from the old bridge. The present bridge consists of seven arches of various spans, but the central one is 5 feet lower than that of the former structure, thus considerably reducing the previously-existing hump.

Under the provisions of the Ancient Monuments Acts, all structures of archaeological and historical interest in the country (including bridges) are scheduled and brought under the protection of H.M. Commissioners of Works, whose approval is necessary under the terms of the Acts before any ancient structure included in the schedule may be materially altered or demolished. A beneficial influence on the design of bridge elevations is also exercised by the Royal Fine Art Commissions, without whose advice no new bridges of any importance are erected nor existing bridges of this class improved in such a way as to alter their elevations.

Estimates of Cost.

When the cost of new road construction is being estimated on a mileage basis for the purpose of a rough preliminary forecast, it is considered that a reasonable average inclusive figure to take, to cover all constructional road and bridge works, land acquisition, and legal expenses, for a new 120-foot road with the layout of *Figs. 4* (*c*) (p. 76) is £80,000 per mile.

Under the average conditions met with in the English countryside, the extent and cost of the bridging operations involved in arranging for conflicting streams of traffic to cross one another at different levels is considerable, as may be seen from the following figures.

Five by-pass schemes which have recently been under consideration cover an aggregate length of 31 miles. Accurate large-scale working drawings for these schemes are not yet available, but the estimates have been prepared from preliminary plans, and longitudinal sections based on levels taken along the selected routes. It is found that the complete elimination by bridging of all junctions and crossings on the level between the proposed new roads and existing roads would necessitate twenty-nine bridges over railways, rivers, and subsidiary roads, and twenty-four bridges under railways and subsidiary roads. This represents an average expenditure of about £23,500 per mile on bridge works, which is equivalent to nearly 26 per cent. of the average total expenditure per mile. The estimated average cost of acquiring the necessary land amounts to about £6,500 per mile.

For preliminary estimating purposes the surface constructional works of a new road conforming with the layout of *Figs. 4* (*c*) are usually priced at £35,000 per mile. The reduced quantities for the layout shown in *Figs. 4* (*d*) would represent a saving of about £2,000 per mile.

These prices include normal site-clearance, excavation, and filling 1 foot thick to the formation width, surface-water drainage, construction of two 22-foot concrete carriageways, two 9-foot cycle-tracks, two 6-foot footpaths, soiling of verges to 46 feet aggregate width, erection of fencing and planting of quick hedges, planting of trees and shrubs, supervision, testing of materials, and contingencies (10 per cent). The extension of the carriageway slab by 10 inches or so on each side for the purpose of forming a well-defined edge, would add about £1,400 per mile to the initial cost of the road.

The cost per square foot of bridge works in new construction is, of course, influenced by many variables, notably span, height, nature of subsoil, form and materials of construction, and (in the case of railway bridges) whether they are underline or overline. For all average conditions likely to be met with in Great Britain, however, it may be said that, in round figures, bridges over rivers, canals, and subsidiary roads may cost from about 35*s*. 0*d*. to £5 per square foot, that overline railway bridges will vary in cost from about 35*s*. 0*d*. to about £4 per square foot, and that the cost of underline bridges will vary from about £6 to £10 per square foot. A steel plate-girder swing bridge, having a span of 108 feet and a width of 32 feet 6 inches, which was constructed a few years ago to carry a new road over a canal, cost £8 per square foot.

TRAFFIC-SIGNS.

The Minister of Transport, in December 1931, appointed a Departmental Committee to consider and report on the matter of traffic-signs. It was composed of representatives of all road and transport interests, including the highway authorities, the motoring and cyclists', etc., associations, the police, and various Government Departments.

In May 1933 this committee presented an exhaustive report[1], as a result of which, in December 1933, the Minister issued Regulations and Directions under the provisions of Section 48 of the Road Traffic Act, 1930. These required, amongst other things, that highway authorities should have regard to the recommendations of the committee in erecting traffic-signs in their respective areas, and that they should be confined to those authorized by the regulations. By this means a large measure of uniformity has been achieved in the traffic-signs used on the public highways, both in the towns and in the rural areas.

Apart from automatic light-signals, the three most important signs are (1) the "HALT at Major Road Ahead" sign, (2) the "SLOW. Major Road Ahead" sign, and (3) the advance direction-sign. All advance warning signs are surmounted with red triangles studded with reflectors.

[1] "Report of Departmental Committee on Traffic Signs." H.M. Stationery Office, London, 1933.

The first-mentioned sign, which is self-explanatory, is primarily intended for junctions at which visibility is restricted. As the contravention of signs of this type is an offence under the Act, it is illegal to erect them without first obtaining the special authority of the Minister of Transport in each case. The third sign referred to above indicates diagrammatically the character of the junction ahead, with road numbers shown in large, and place names in small, lettering.

Research and Experimental Work.

General.

Statutory authority to carry out experimental work was conferred on the Minister of Transport by the Roads Improvement Act, 1925, and the need for extended scientific methods was recognized by the establishment, in 1929, of a Road Research Laboratory.

The control of this laboratory is now vested in the Department of Scientific and Industrial Research, which is advised in the conduct of the work by a Road (Materials and Construction) Research Board, composed of engineers and scientists versed in the various phases of the subject, under the chairmanship of the Chief Engineer of the Roads Department of the Ministry of Transport.

In order to correlate research with practice, the work of the Board is closely associated with that of the Experimental Work on Highways (Technical) Committee of the Ministry of Transport, under whose advice and direction, and with the co-operation of the highway authorities, full-scale experiments are conducted on roads in various parts of the country.

Stated briefly, the function of the laboratory is to investigate the fundamental principles underlying the behaviour of the materials used in road construction, to develop methods of measuring and recording the action of the materials under traffic, and to devise laboratory-testing procedure that will materially shorten the long period which must otherwise elapse before an opinion can be formed on the results obtained under practical conditions.

The work falls under the following main headings: (1) soil-mechanics (earthworks and foundations), (2) materials and methods of construction (bituminous surfacings and concrete), and (3) road-mechanics, including (*a*) surface characteristics, (*b*) forces between vehicle and road surface, and (*c*) statistics. It is not possible in the space available to refer to all the laboratory's activities, but mention may be made of two or three sections of the work.

Bituminous Research.

One of the largest sections is that relating to bituminous materials, and much of this work is carried out in co-operation with the manufacturers' associations. Extensive laboratory researches are in progress to investi-

gate the mechanical properties of bituminous materials and the most suitable proportions of binder, filler, and aggregate for various purposes. Following these tests, mixtures are selected for trial on the laboratory's road-testing machines, and subsequently for full-scale trials, in co-operation with the Ministry of Transport, on public roads.

Three road-testing machines, with mean diameters of 5 feet 6 inches, 38 feet 6 inches, and 110 feet, respectively, have been designed and constructed at the laboratory. The smallest machine is of the mortar-mill type. It produces the most rapid destructive effect, but departs most from actual road conditions. The 38-foot 6-inch machine consists of eight wheels, which are mounted on steel arms attached to a central spindle and which revolve on the testing track at speeds of from 16 to 20 miles per hour.

The largest machine is an ordinary commercial lorry, weighing 12 tons when fully loaded, and driven electrically at speeds of up to 45 miles per hour on the test track, which is 10 feet wide and has a mean diameter of 110 feet, the trafficked portion consisting of two 3-foot widths corresponding to the nearside and offside wheels of the lorry. This machine approximates most closely to road conditions, but takes a correspondingly longer time than machines Nos. 1 or 2 to test a material to destruction. It is at present used principally for testing surface dressings.

The object of testing a bituminous surfacing material on a road-machine is to enable a forecast to be made of the useful life that it would have under traffic conditions on any particular road, but this cannot be determined simply on the basis of a traffic test, since other factors—particularly weather and climatic conditions—exert a very important influence on the useful life of road materials. These factors are being studied at the laboratory, both in relation to the existing road-machines and with a view to incorporating the essential effects in a new type of machine. As part of this work, experimental surfacings are under observation on a section of public road which is conveniently situated close to the laboratory and contains a 30-foot carriageway, carrying about 18,000 tons of traffic per day. Experiments are constantly being carried out on this road in co-operation with the Ministry of Transport, and forty-four sections of bituminous carpet are at present undergoing test and examination.

Road-Mechanics.

Great importance is attached to the preservation of non-skid surfaces, and it is therefore necessary that those responsible for road maintenance should have at hand a ready means of measuring the frictional or non-skid properties of the various materials in use. For this purpose an apparatus has been designed and constructed, consisting of a motor-cycle and side-car fitted with the necessary recording instruments.

When carrying out a test the motor-cycle is driven along the road

with the sidecar wheel fixed at an angle to the direction of motion, and both the load on the wheel, and the normal component of the force tending to restore it to an ordinary running position, are measured. The ratio of the normal force to the load on the wheel is a measure of resistance of the road to skidding, and is called the " sideway-force coefficient." Tests are made with a perfectly smooth tire on the sidecar wheel in order to obtain comparable results, as it has been found that the usual tread patterns on standard tires affect the results according to the amount that the tread is worn. Further, the smooth tire corresponds with the worst case met with under everyday road conditions. Under favourable conditions on the level this machine can test up to a speed of slightly over 50 miles per hour, but tests are normally undertaken up to a maximum speed of about 40 miles per hour.

As, however, this range is not quite sufficient for present-day requirements, a machine of another type, which is capable of registering at over 70 miles per hour, has now been designed and constructed. This apparatus consists of a high-powered car towing two trailer wheels, each fixed at the same angle to the direction of travel. The sideway forces are only measured on the nearside wheel, the purpose of the second wheel being to balance these forces and this to ensure stability at all speeds. Each wheel carries a load of 360 lb. on a 26-inch by 3-inch tire, as in the case of the side-car machine, and thus the results obtained are directly comparable with those given by the motor-cycle and sidecar.

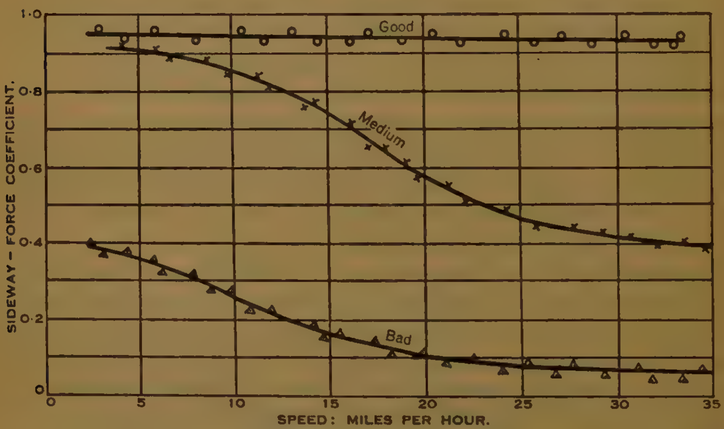
Not only the value of the coefficient, but also its variation with speed, has to be considered in assessing the resistance of a surface to skidding. The standard method of recording the results obtained from a test is to plot a curve showing the relation between the sideway-force coefficient and speed. The principal characteristic of such curves is a reduction in coefficient with an increase in speed. *Fig. 21* (p. 108) shows representative curves for three commonplace, but widely varying, surfaces. The uppermost curve is typical of the results obtained from a good surface, in that it indicates only a slight fall in the value of the coefficient throughout the whole speed-range. The middle curve is typical of the results obtained from a large variety of road surfaces, on some of which the value of the coefficient at high speed may fall considerably lower than shown, notwithstanding the usual high initial value at low speed. The lowest curve differs from the others in that it indicates comparatively low values of the coefficient even at low speed. This is a feature of certain types of surfacing principally to be found in the larger built-up areas. Curves of all intermediate types between those shown may be obtained in various circumstances.

It is essential, however, to appreciate the external conditions under which a test is carried out if the results are to be viewed from the correct angle, since it has been found that there are two factors over which there can be no control, but which exert a considerable influence on the co-

efficients obtained. These are: (1) the "wetness" factor, or the time during a particular rainfall at which the test is made, and (2) the "seasonal" factor, or the time of year at which the test is made. The tests show that, in general, clean dry road surfaces always have a high resistance to skidding, and that (except in the case of frost-bound roads) the lowest values are obtained immediately after rain has commenced, following a prolonged dry spell, but that the values tend to increase as the rain continues. It seems a fair conclusion to draw from this that the frictional resistance of the surface is reduced by a lubricating film of some kind, which is washed away as the result of continued rainfall.

When a road surface is dry, artificial watering is resorted to for the purpose of the tests, and it is found that the coefficients thus obtained

Fig. 21.



RESISTANCE TO SKIDDING WITH SMOOTH TIRES: VARIOUS SURFACES TESTED WHEN WET.

generally tend to be slightly lower than those recorded during steady rain; but this is not inconsistent, nor is it detrimental to the value of the test, since the surface conditions after artificial watering roughly correspond to those existing at the beginning of a heavy shower, after a dry spell.

With regard to the "seasonal" factor, it has been shown that the values of the coefficients recorded during the summer months are, in general, definitely lower than those obtained during the winter months. This applies to practically all road surfaces, and, whilst the reason for it has yet to be fully explained, there is ground for supposing that it may be caused, in part at least, by seasonal changes of temperature. Another theory under investigation is that it is accounted for by some change in the physical properties of the tires themselves.

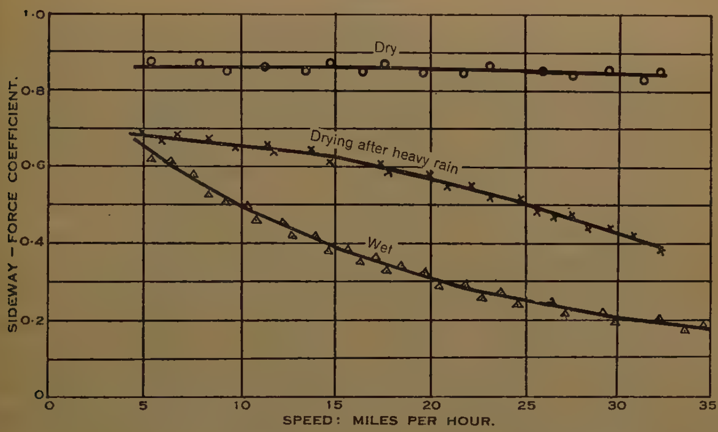
Fig. 22 shows the results obtained from tests of typical asphalt surfaces

under dry and wet conditions respectively, at speeds of up to 40 miles per hour.

No attempt is made to classify a surface as "dangerous" or "safe" merely by specifying numerical limits. In general, however, a surface of normal characteristics giving a coefficient of 0·4 or more at 30 miles per hour may be regarded as reasonably safe, and a value of 0·2 or less indicates a surface which may give rise to dangerous conditions. Between these values the degree of safety depends very much upon the traffic conditions and the location of the surface, when considered in relation to its characteristics at lower speeds.

Amongst the other apparatus in use at the laboratory is a profilometer, which has been designed to measure irregularities in road surfaces, and has

Fig. 22.



Resistance to Skidding with Smooth Tires: Tests on Asphalt Surfaces.

considerable practical value. This instrument records graphically the longitudinal profile of the road through the vertical movements of a recording wheel relative to a datum, provided by sixteen other wheels which carry the apparatus along the road surface. The wheels are spaced irregularly in order to counteract the effect of recurring waves related to the distance apart of the wheels. The sum of these movements, expressed as inches per mile, is recorded automatically, and furnishes an indication of the riding qualities of the road surface. The apparatus is also fitted with a "classifier" which classifies the irregularities according to their severity.

In considering sideway-force coefficients in relation to the textures of road surfaces, it is necessary to have accurate information regarding the form and size of the areas of contact between the tire and the road, and a simple method of obtaining contact prints has therefore been devised. The area to be tested is brushed over with printer's ink, a rubber roller is

then passed over it, and the impression so obtained is transferred to a sheet of plain paper. By this means prints can be produced which show with a remarkable amount of detail the changes which take place under traffic in the texture of the surface, and disintegration can readily be detected.

Methods have also been devised for measuring the impact forces between the road and the wheels of various types of vehicles, as well as the distribution of pressure on tires, and for examining numerous other factors which are of scientific interest in determining the relationship between the road and the vehicle.

Reports of the Road Research Board and of the Ministry of Transport Experimental Committee are issued annually, and the results of special researches and investigations are published as separate documents from time to time*.

Street Lighting.

In June 1934 the Minister of Transport appointed a Departmental Committee representative of the interests concerned, under the Chairmanship of the Chief Engineer of the Roads Department, to consider and report on the subject of street lighting.

The comprehensive Report which they submitted in August 1937 * is likely to form the basis of future practice for some years to come. The following is a summary of the principal recommendations.

(1) There should be reasonable uniformity in the lighting of portions of traffic routes presenting similar characteristics, but minor variations are not necessarily disadvantageous.

(2) Consideration should be given to the responsibility for the lighting of traffic routes being confined to large administrative units, and to the suggestion that the cost of lighting roads should be aided by grants from national funds administered by the responsible Government Department.

(3) Adjoining authorities should confer together with the object of securing uniformity of lighting on routes of common interest.

(4) Power to control extraneous lighting should be given to lighting authorities, but only in so far as it may be seriously detrimental to the street lighting.

(5) Street-lighting installations should be complete in themselves, and no reliance should be placed on extraneous lighting.

(6) Two ranges of lighting should be adopted, for traffic routes and other roads respectively, with a definite gap between them. Traffic routes are defined as roads on which the standard of lighting should provide an ample margin of safety for all road users, without the use of headlights by motor-vehicles. Other roads are defined as those which the responsible authority considers should be lighted.

* Published by H.M. Stationery Office, London.

(7) In the case of lighting schemes on traffic routes the following principles should be observed :—

(*a*) The mounting-height should be of the order of 25 feet.
(*b*) The average spacing should not exceed 150 feet, or, where economically practicable, 120 feet; the maximum spacing in any one span should be 180 feet.
(*c*) The overhang of the lanterns should vary according to the width of the carriageway.
(*d*) On straight sections of road sources should be placed on both sides of the road in staggered formation; additional central sources should be placed in every third span when the carriageway-width exceeds 40 feet.
(*e*) On bends the sources should be placed on the outside of the curve. Particular attention should be given to siting at bends, junctions, and intersections.
(*f*) Subject to certain reservations (specified in the Report), central suspension should generally be avoided.
(*g*) The lantern output per 100 linear feet should be between 3,000 and 8,000 lumens, according to the conditions prevailing on the highway and the type of installation.
(*h*) Excessive glare may be largely avoided if the ratio used to express the concentration of the light does not exceed 6, or preferably 5.
(*i*) Pending the results of further experience, dual carriageways should be lighted as though each carriageway were an independent traffic route; additional lighting required, for example, for service roads, should be of the type recommended for roads other than traffic routes.

PLANNING.

It has been shown in the historical review (pp. 56 *et seq.*) that for many centuries there was no national scheme or plan for the roads of the country, and that its absence has been instrumental in producing the traffic conditions which the present generation is endeavouring to improve. Even in the post-war era planning in relation to roads did not receive the attention which its importance deserved. In recent years, however, it has become increasingly recognized that the road system must form the basis or framework of every plan for organized future development, whether it be on a regional or on a national scale, and the Town and Country Planning Acts, later supplemented by the Restriction of Ribbon Development and the Trunk Roads Acts, have provided the Authorities concerned with powers to plan new traffic routes and to safeguard them from building development.

The opinion is strongly held in some quarters that the proper solution of the British road problem is to construct a system of national roads reserved exclusively for motor traffic, on the lines of the German *Autobahnen*, which have attracted much attention. In March 1939 a Select Committee of the House of Lords, which was appointed to report on the best means of preventing road accidents, recommended the construction of one motorway. Whilst appreciating the fact that Great Britain is a comparatively small country, more industrialized and far more densely populated than Germany, and that methods which may be suitable in that country are not necessarily applicable to Great Britain, the Committee expressed the view that the success or otherwise of the experimental motorway which they recommended would determine whether or not it was sound policy to adopt such a scheme for Great Britain.

Although the Trunk Roads Act of 1936 is a step in the right direction, in that it puts the principal roads of the country for the first time under the control of a central authority (namely, the Minister of Transport), enabling him to apply a national outlook to those roads, nevertheless it gives him only limited powers (as explained below) for the construction of new roads, and fresh legislation would be necessary before the Government could embark upon the construction of a new system of national roads, whether or not they were to be devoted to the sole use of one form of traffic.

The provision of motorways on the scale necessary to achieve any marked results would obviously be a costly undertaking, justification of which is very largely a question of economics, involving many factors which would call for consideration in relation to the social development of the country as a whole. In any event it is clear that highway engineers in Great Britain are faced with the knowledge that for many years to come a very large proportion of the total mileage of the roads for which they are responsible must continue to serve the needs of mixed traffic, and that road design must be adapted to those conditions.

Section 1 (3) of the Trunk Roads Act, 1936, empowers the Minister of Transport to plan and construct new roads as diversions from existing trunk roads. The effect of statutory Orders made by the Minister under this section is to impose the restrictions on building and access provided for in the Restriction of Ribbon Development Act (p. 64) on the routes selected for such diversions as may be found necessary for the improvement of alignment and for the by-passing of built-up areas, thus protecting them from building-development until traffic considerations justify the constructional works being put in hand. During the period of 2 years and 3 months which ended on the 30th June last, two hundred and eighteen such Orders were made, relating to a total length of 322 miles of new-road construction in by-passes and diversions.

These notes would be incomplete without reference to the highway

development plan which has been prepared for the London Traffic Area. This takes the form of a Report entitled "Highway Development Survey 1937 (Greater London)[1]" which is the outcome of 3 years' close study of the complex problem of the road communications of the Metropolis and its environs undertaken by Sir Charles Bressey, C.B., C.B.E. (formerly Chief Engineer of the Roads Department, Ministry of Transport), in collaboration with Sir Edwin Lutyens, K.C.I.E., R.A. It is unfortunate that the publication of this Report has coincided with an era of abnormal expenditure on rearmament and defence measures. It can but be hoped that the time will soon come when the Government and the highway authorities will feel able to deal with this and many other important road projects which, under the present conditions, remain in abeyance.

Expenditure.

It will perhaps be of interest to look for a moment at the expenditure involved in maintaining and improving the road system of the country.

For statistical and administrative purposes the term "maintenance" is held to include practically all works that are undertaken within existing highway boundaries, other than the diversion, duplication, or drastic widening of existing carriageways, or the widening or reconstruction of bridges. As thus defined, the expenditure involved in the upkeep of the public highways of Great Britain (including cleansing, snow-clearing, and reinstatement works) amounts to over £40,000,000 per annum, but if to this sum be added the cost of all schemes of major improvement and new construction, together with administrative expenses and loan charges on capital works, the resultant figure approaches £70,000,000 per annum.

The average cost of maintenance only per mile, for the financial year 1936–37, including minor improvement works within existing highway boundaries, but excluding administrative expenses, is indicated in Table XI.

Table XI.—Maintenance Expenditure for the Year Ended the 31st March, 1937.

Category.	Average cost per mile (England only).	
	Counties.	County boroughs.
	£	£
Class I roads	447	592
Class II roads	309	454
Unclassified roads	100	211

[1] Published by H.M. Stationery Office, London.

8

Conclusion and Acknowledgements.

It is an understatement to say that good roads are a national asset. At the present stage of civilization they are indispensable to the social and economic welfare of every organized community. The problem of how the principal roads of the country shall be fitted for the insistent demands of present and probable future traffic is one of the many facets, which is worthy of the highest endeavours of every highway engineer.

The Author gratefully acknowledges the advice and encouragement which he has received in preparing this Paper from Mr. F. C. Cook, C.B., D.S.O., M.C., M. Inst. C.E., Chief Engineer of the Roads Department of the Ministry of Transport. No less does he appreciate the co-operation of those of his Departmental colleagues who have assisted in supplying information and in checking the numerous figures included in the Paper.

Finally, whilst this survey is intended to be primarily a record of facts and of current procedure, the Author wishes it to be understood that any expressions of opinion which it contains are his own, and should not be taken as representing the official views of the Department which he has the honour to serve.

PLATE 1.
BRITISH ROAD DEVELOPMENT.

estion is selected from the curve

sses. In a freely-supported span
ort: the full span; (c) for shear

s with the loaded length, and which
) An invariable knife-edge load of
buted load, be most effective, that
at the support: at the support;

avy axle over the other axles, this

iteract the over-dispersion of the

rting members, irrespective of the

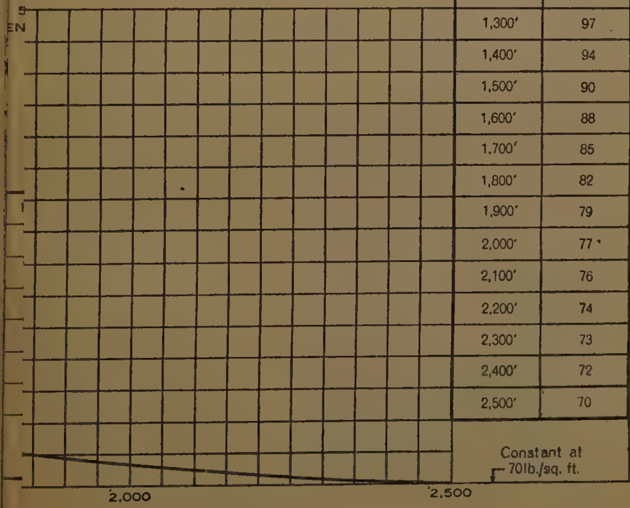
to them (that is, parallel with

. per foot run of beam).
oad allocated to them shall be that

en as acting in conjunction with

TABULATED VALUES.

Span	lb./sq. ft.
100′	208
150	192
200′	180
250′	170
300′	163
350′	156
400′	150
450′	145
500′	140
600′	132
700′	125
800′	119
900′	114
1,000′	108
1,100′	104
1,200′	100
1,300′	97
1,400′	94
1,500′	90
1,600′	88
1,700′	85
1,800′	82
1,900′	79
2,000′	77
2,100′	76
2,200′	74
2,300′	73
2,400′	72
2,500′	70



J. G. PIDGEON.

ABSTRACTS OF THE CURRENT TECHNICAL LITERATURE OF ENGINEERING AND APPLIED SCIENCE.

ENGINEERING CONSTRUCTION.

Miniature System of First-Order Alignment and Triangulation Control. F. W. Hough (**Proc. Amer. Soc. Civ. Engrs.*, 65, *1707–1717 ; Dec. 1939*).—The Author describes an unusual type of survey made at the Tygart dam, near Grafton, W.Va., which has a total length at the top of 1,921 feet. The method of horizontal alignment control is intended not to replace, but to supplement, triangulation. A survey of this type involves the study and determination of possible small horizontal movements in a large engineering structure, such as a dam, as well as of contributing factors in the immediate vicinity. The purpose of the work described is to develop a suitable means for measuring the direction and amount of any horizontal movements in the various monoliths of the dam, to supplement the data obtained from the strain gauges installed in the dam, and to determine ground-movements in the surrounding area.

Measurement of Fluids with Orifice and Flow-Nozzle. H. Escher (**Commonwealth Engr.*, 27, *119–125 ; 1 Nov. 1939*). The Author reviews recent research work carried out in various countries, and makes a critical comparison of the methods adopted. A bibliography of fifty-seven references is appended to the article.

Investigations of Vortex and Energy Losses in the Diverging Flow of Water. Atsushi Miyadzu (**Tech. Rep. Tohôku Imp. Univ.*, 13, *93–235 ; 1939*).—The Author presents a new formula for the eddy loss of head, on the basis of the coefficient relative to the form character of the boundary, first clarifying the theoretical relation between the eddy loss due to induced vortexes and the mean pressure on the transition-boundary inducing the formation of vortexes. He describes his experimental investigations in detail, from which he concludes that the obstacles existing in the region of the vortex have the effect of reducing the eddy loss of head, provided that they do not project into the region of the main stream and do not considerably disturb it.

Notes.—An asterisk prefixed to a reference, thus **Proc. Amer. Soc. Civ. Engrs.*, denotes that the article is illustrated.

The abbreviated titles of periodicals are those used in the "World List of Scientific Periodicals" (Oxford 1934).

The Pressure-Momentum Theory applied to the Broad-Crested Weir. H. A. DOERINGSFOLD and C. L. BARKER (**Proc. Amer. Soc. Civ. Engrs.*, 65, *1719–1731 ; Dec. 1939*).—The Authors discuss the general theory of pressure-momentum and its application to the broad-crested weir, and present the results of tests made at the University of Minnesota and at the State College of Washington, Pullman, Wash. They conclude that the flow over a broad-crested weir may be computed accurately by the use of the formulas developed.

Tremie Concreting of Bridge Foundations. W. F. WAY (**Engng. News-Rec.*, 124, *19–20 ; 4 Jan. 1940*).—The Author describes the method adopted to form a protective coating of concrete economically and effectively at the base of a bridge-pier at the Ruskin power-station, British Columbia, where the rock was subject to severe erosion from water flowing in the spillway. The quantity of concrete involved was 750 cubic yards, and it was deposited through tremies by a method devised to avoid either horizontal joints between successive pours or dangerous stresses in forms large enough to support the whole mass of fresh concrete. In addition to the work on the bridge-pier, 940 cubic yards of concrete was deposited just downstream from the dam, to repair rock eroded from the spillway. This concrete was placed in water ranging from 10 feet to 65 feet in depth, with similar equipment.

Steel-Pile Piers for Railway Bridges. (**Engng. News-Rec.*, 123, *826–827 ; 21 Dec. 1939.*)—On recent bridgework of the Canadian National Railways a type of pier has been developed, in which steel H-piles not only serve as the bearing structure below ground, but also comprise the pier structure. A typical steel-pile pier consists of closely-spaced 12-inch 53-lb. H-sections of copper-bearing steel covering the entire area of the pier and evenly spaced in rows. The tops of the piles are arc-welded in the field to 15-inch 33·9-lb. channels which form a cap for the bearing of the steel grillages used to support the superstructure. The pile sections are supplied in lengths up to 70 feet. The application of this system to four bridges is described.

Concrete Aggregate Development on the Claytor Hydro-Electric Power Project, Virginia. G. W. HUTCHINSON (**J. Amer. Concrete Inst.*, 36 (*Proc.*), *273–295 ; Jan. 1940*).—The project consists of a gravity dam approximately 1,150 feet in length, having a maximum width at the base of 108 feet and a maximum height from rock to the top of the spillway gates of 123 feet, together with a power-station housing four generating units, each of a rated capacity of 26,000 horsepower. The work involved the deposition of about 250,000 cubic yards of concrete. The Author describes the development of fine and coarse aggregate and studies of particle shape and gradation which resulted in the production of a stone

sand of high quality. A feature was the use of relatively large quantities of the dolomitic aggregate passing a No. 100 sieve, in concrete of relatively low cement-content in the mass, or in unexposed work. A saving of several hundreds of thousands of dollars on concrete construction was effected by these methods.

Heightening a Long Highway-Bridge. E. Harsch (**Engng. News-Rec.*, 123, *757–761 ; 7 Dec. 1939*).—As a result of the creation of a reservoir by the construction of the Guntersville dam by the Tennessee Valley Authority, the concrete viaduct approaches of the 767-foot-long three-span continuous steel bridge over the Tennessee River at Guntersville were flooded and the shipping clearance was reduced considerably. The steel bridge was accordingly raised 17 feet by jacks, whilst the concrete viaduct was raised by a gantry crane, having a height of 80 feet and a span of 55 feet, which lowered the spans to the ground, or held them suspended, while old bents were raised or new higher bents were constructed on new piles. The total length of the bridge raised is 2,505 feet, whilst 766 feet of approach viaduct was demolished and replaced by an earthen embankment. The work was executed in 71 days.

Provision for Seismic Forces in the Design of the Golden Gate Bridge, San Francisco. L. S. Moisseiff (**Civ. Engng., N.Y.*, 10, *33–35 ; Jan. 1940*).—The Author discusses in detail the analyses of earthquake forces involved in the design of the bridge, which was completed in 1937. He observes that the flexibility of a suspension-bridge is of considerable assistance in resisting earthquake stresses ; moreover, the frequency of a destructive earthquake can never be in resonance with any part of the Golden Gate structure. The effect of the " design quake " upon the superstructure is less than that of a wind load of 30 lb. per square foot, and the highest shears induced by it in the substructure are not more than 10 lb. per square inch.

The First Vehicle-Tunnel under the East River, New York. (**Engng. News-Rec.*, 123, *830–833 ; 21 Dec. 1939.*)—Twin tunnels, respectively 7,400 feet and 7,865 feet in length, are being constructed between Manhattan and the borough of Queens in order to relieve congestion on the bridges over the East River. The factors controlling the location are discussed and the design of the approaches to meet traffic needs is described. Comparative data for the tunnel and for the Lincoln and the Hudson vehicular tunnels are tabulated. The cost of the new tunnels is estimated at more than $58,000,000.

Driving the Queens–Midtown Vehicular Tunnel, New York. (**Engng. News-Rec.*, 124, *29–34 ; 4 Jan. 1940.*)—The boring of the twin 31-foot diameter highway tunnels under the East River, referred to in the preceding

Abstract, was successfully completed on the 8th November, 1939. The nature of the ground, which consists of rock, earth, mud, and riprap, rendered the operations unusually difficult. The driving was effected by shield and compressed air. Gravel packing and grouting were used to provide a firm support for the cast-iron lining.

Theory of Elastic Stability applied to Structural Design. L. S. Moisseiff and F. Lienhard (**Proc. Amer. Soc. Civ. Engrs.*, 66, *31–70 ; Jan. 1940*).—The Authors discuss the basic laws governing the buckling of metal elements forming structural members, and analyse the behaviour of these elements when subjected to various stress conditions. The results are applied to unstiffened plates of columns and girders, and also to structural parts reinforced by stiffeners. Simple rules for practical design are presented, with Tables and diagrams to facilitate the work.

Reinforced-Concrete Poles. J. R. Marks (**Proc. N.Z. Instn. Engrs.*, 25, *155–158 ; 1939*).—The Author presents an economic survey of the design, weight, and cost of reinforced-concrete poles, discusses the cold working of steel by twisting, and the effect of twisted steel upon the cost and weight of poles, and reviews the origin and development of I-section poles. His general conclusions are as follows : each pole requires individual designing from top to bottom ; a continuous type of web is preferable to a broken or lattice type ; when testing poles, the observer should not be unduly influenced by localized phenomena which may occur after the pole as a whole has lost its useful purpose by crippling.

Design and Construction of Explosives Factories. C. L. Boucher and D. Bagley (**Struct. Engr.*, 18, *473–482 ; Jan. 1940*).—The Authors discuss the design, construction, and erection of factories, and the modifications required to meet the danger of attack by aircraft. They deal in detail with a commercial-explosives factory, a military-explosives factory, a propellants factory, and propellants factories designed to limit or prevent undue interruption of work by aerial attack. In an Appendix brief descriptions of a few of the principal explosives are given.

Application of Dimensional Analysis to Stresses in Railway Tracks. V. M. Daniloff (**Engineering*, 148, *660–661 ; 15 Dec. 1939*).—The Author points out that Timoshenko's theory of track-deflexion applies to static conditions only, and that the complete analytical solution of the problem when moving loads and sleeper-deformation are considered, is too involved to be of much practical value. He then outlines his method, and obtains expressions connecting the various factors involved. He concludes that, when strengthening the track to carry greater axle-loads at higher speeds, without change in the value of the maximum rail-stresses, the sleepers must be strengthened in the same proportion as the rails, but that their

number may be reduced; and that the ballast resistance need not be changed. The correct design of the motive-power equipment in regard to the value of the unbalanced forces is also stressed.

Improvements at the Port of Rangoon. (**Dock Harbour Auth.*, 20, *53–58; Jan. 1939*).—In October 1934 the Port Commissioners decided to construct a new two-berth wharf to replace an old screw-pile jetty built in 1882. The new wharf is 900 feet in length with an average width of 190 feet, and is constructed throughout of reinforced concrete. A minimum depth of 25 feet is available at low water. The front portion is carried on 150 screw-cylinders penetrating 40–45 feet below the river-bed. The remainder is carried on 925 reinforced-concrete piles, 18 inches by 18 inches, ranging in length from 50 feet to 75 feet. Detailed descriptions are given of the constructional work, and of the transit-sheds, cranes, and lifting appliances. Brief reference is made to further new works of a minor character.

Chicago River Control-Works. H. P. RAMEY (**Proc. Amer. Soc. Civ. Engrs.*, 66, *71–103; Jan. 1940*).—The control-works constructed in 1939 by the Sanitary District of Chicago prevent the polluted Chicago river from entering Lake Michigan. They consist of walls making a watertight enclosure around the river mouth, a navigation lock to pass shipping, and two sets of control-gates to regulate the quantity of water admitted into the river from the lake. Detailed descriptions are given of these works, of the novel design of the lock gates and walls, and of the operation of the controlling machinery. The benefits derived from the works include the creation of an inner harbour, better control over the flow in the Chicago river and the main drainage canal, and insurance against reversal of flow of the river into Lake Michigan, but at the expense of navigation—which is, however, not of great importance, as most of the larger ships using Chicago harbour dock at the Navy pier outside the control-works.

The Action of Water upon Copper Pipes. L. TRONSTAD and R. VEIMO (**J. Inst. Metals*, 66, *17–32; Jan. 1940*).—The Authors describe laboratory experiments made at Trondhjem, Norway, with copper pipes and drinking water containing various additions, under stagnant conditions, to study the reactions governing the dissolution of copper and the possible precautionary measures to be taken against the attack of copper pipes by drinking water under service conditions. They suggest as a remedial measure the addition of lime to the water to increase the *p*H-value to 8·5.

Reaction of Heavy Doses of Chlorine in Various Waters. A. E. GRIFFIN (**J. Amer. Waterw. Ass.*, 31, *2121–2129; Dec. 1939*).—The Author reports the results of a study by a Research Committee of the Association,

which indicate that in practically all waters the residual curves produced by varying chlorine doses and standard periods of contact will conform to the same general pattern, characterized by an initial rise in residual followed by a dip that is immediately followed by a secondary rise, which will parallel the chlorine dose; that the odour of the water may increase with the first rise in residual, but will usually disappear or become so reduced that it can be readily removed by de-chlorination; and that little bacterial life can persist when chlorination is carried into the zone of true oxidizing residuals, that is, in the zone where the residuals rise following the dip.

Concrete Linings for Irrigation Canals. C. W. Wood (**Civ. Engng., N.Y.*, 10, *29–32; Jan. 1940*).—The Author reviews the history and the results of work carried out on two large projects in California, and describes the highly-mechanized methods of lining construction used on various recent jobs.

Model-Experiments in Relation to Energy-Diffusers in Water Overflows. L. Escande (**Gén. Civil*, 115, *429–433; 16 Dec. 1939*).—The Author describes tests made on a scale model of an energy-diffusing installation. The theory of similarity is adapted to the discussion, with special reference to the entrainment of air. A short description is given of the energy-diffusing installation of the Carcanet works in the Aude valley, France.

MECHANICAL ENGINEERING.

The Case for Automatic Boiler-Control. (*Power & Works Eng.*, 34, *461–464; Dec. 1939.*)—Since the introduction of automatic boiler-control discussion has tended to centre upon the means to the end rather than upon the end in view, with the consequence that the adoption of automatic control has lagged, to the disadvantage of the boiler-plant owner. Therefore a study is presented of the purposes and economic advantages of the principle, and it is stated that any change of method must be justified by a reduction in operating cost. Manual and automatic control are compared, and the fundamentals of boiler-operation are discussed.

Load Pick-up of Stand-by Steam Power-Stations. F. G. Philo (**Gen. Elect. Rev.*, 42, *520–524; Dec. 1939*).—The loads accepted by steam stand-by stations may be either peak-loads or sudden and violent increases in load due to failure of other generating or transmitting plant. The Author discusses the problems involved, including the heat stored in the boilers, and the relation between steam-pressure and maximum turbine load, and presents the results of observations made at the Long Beach power-station, California. He states that since the initiation of the system described, many load-increases of various magnitudes have been successfully accepted at Long Beach.

Underground Bomb-Proof Stand-by Power-Station at Berne, Switzerland. E. BAUMANN (**Bull. Assoc. Suisse Elect.*, 30, *786–790 ; 29 Dec. 1939*).—The Author describes the construction of an underground station, to afford complete protection against aerial attack. It contains a Velox boiler with an output of 42 tons of steam per hour and a turbo-generator set of 9,000 kilowatts. The cost of construction amounted to 150 *francs* per kilowatt. The whole installation occupies no more space than the boiler house constructed 35 years ago for a steam-turbine of 2,500 kilowatts.

The Damping of the Torsional Vibration of the Shafts in Engines fitted with Speed-Reducing Gear. G. LEHR (**Bull. Ass. Tech. Mar. Aér.*, 43, *495–517 ; 1939*).—The Author develops general formulas for determining the amplitude of the shafts in an engine fitted with speed-reducing gear, and applies them to engines with different types of reduction gear.

Cooling on the Front of an Air-Cooled Engine Cylinder in a Conventional Engine Cowling. M. J. BREVOORT and U. T. JOYNER (**Rept. Nat. Adv. Ctee. Aero., No. 674, 13 pp. ; 1939*).—The Authors describe measurements made of the cooling on the fronts of model-cylinders in a conventional cowling under both ground and cruising conditions. For the front of the cylinder an optimum fin-width was found to exist, beyond which an increase in width reduced the heat-transfer. The heat-transfer coefficient on the front of the cylinders was larger on the side of the cylinder facing the propeller-swirl than on the opposite side, and this effect became more pronounced as the fin-width was increased. The results obtained are plotted in numerous curves.

Influence of the Pressure and the Explosion-Speed upon the Mechanical Fatigue of an Internal-Combustion Engine. O. DUROUCHOUX, R. MARCHAL, and F. RISLER (**Bull. Ass. Tech. Mar. Aér.*, 43, *473–490 ; 1939.*)—With the aid of a quartz piezo-electric manograph of very low inertia, and using a compression-ignition engine in which the combustion was very rapid, the Authors investigated the influence of the development of the pressure during the combustion phase, and they have derived a method of calculation taking account of these phenomena. They describe the experiments in detail and discuss the industrial applications of the method.

Running Gear for Diesel Engines. (**Diesel Engine Users Ass., Paper No. S.154, 26 pp. ; 1939.*)—In a symposium thirteen British manufacturing firms discuss problems connected with running gear, including the arrangement of pistons and connecting-rods ; the relative advantages of various types of big ends ; the clearances between pistons and liners and pistons

and piston-rings; methods of fixing the cylinder-head; arrangement of cooling pistons; and water and gas joints. Stationary, locomotive, marine, and vehicle engines are covered by the symposium.

The Manufacture and Assembly of High-Speed Diesel Engines. (**Machinery*, 55, *325–329; 28 Dec. 1939.*)—Detailed descriptions are given of the methods and equipment used at a works in Northamptonshire for machining connecting-rods and cylinder-heads of Diesel engines. Turret lathes are employed for machining many of the smaller stampings and castings. Various sub-assemblies are completed on benches arranged transversely in relation to the main assembly-track so that they are completed near to the point on the track at which they are handled.

Electronic Voltage and Speed Control of Alternators. J. H. Piddington (**J. Instn. Engrs. Australia*, 11, *375–379; Nov. 1939*).—The Author outlines briefly the theory of voltage- and speed-control of rotary electrical equipment by high-vacuum electronic valves, and indicates the limits of the range over which control is practicable. He describes control apparatus for a 15-kilovolt-ampere sine-wave alternator test. The results indicate that under steady load conditions a frequency-stability of 0·004 per cent., and a voltage-stability of 0·008 per cent., were obtained with this apparatus.

New 2–8–8–4-type Locomotives for the Southern Pacific Lines. (**Rly. Age*, 107, *918–922; 16 Dec. 1939.*)—Twelve 2–8–8–4-type locomotives for passenger and freight traffic have been recently delivered to the Southern Pacific lines. The four cylinders have a diameter of 24 inches and a stroke of 32 inches, the coupled wheels have a diameter of 5 feet 3½ inches, and the boiler-pressure is 250 lb. per square inch. The total heating surface is 9,749 square feet (6,918 square feet evaporative), and the rated tractive effort is 124,300 lb. The tender, carried on six-wheel bogies, has a water-capacity of 22,120 U.S. gallons, and a coal-capacity of 28 short tons. The engine and tender weigh 540¾ short tons in working order. Among the special features is a system of water-sprays on the driving- and tender-wheel tires, which come into action automatically when the brakes are applied, thus counteracting the heating effect of the brake-shoes.

Diesel-Electric Shunting Locomotives for the Chicago, Rock Island and Pacific Railroad. (**Rly. Age, Chicago*, 107, *879–881; 9 Dec. 1939.*)—A description is given of two B_0–B_0 diesel-electric shunting locomotives. Each locomotive is fitted with two 180-horsepower four-stroke-cycle eight-cylinder diesel engines, each direct-coupled to a generator. Nose-suspended traction-motors are used. The engines weigh 44 short tons and develop a maximum tractive effort of 24,800 lb. at 2·5 miles per hour.

Each locomotive is computed to have enabled an annual saving of more than \$5,500 in maintenance and running costs to be effected, as compared with the charges for equivalent steam power.

550-Horse-power B_0–B_0-type Battery Shunting Locomotives for the London Passenger Transport Board. (**Engineering*, 149, *85–86; 26 Jan. 1940*).—The conditions called for in the design of the locomotives, which are used for maintenance and constructional purposes, included the following: two locomotives, one at each end of a train, were to be capable of hauling a load of 200 tons up a gradient of 1 in 61, with occasional lengths of 1 in 40; were to be able to inch such a train up a gradient of 1 in 30 on a rough constructional track; and were to be able to haul a 100-ton cable-laying train at a steady speed of 2–3 miles per hour without jerking. The locomotives are fitted with four 138-horsepower 600-volt traction-motors, supplied at half-voltage from a 160-cell lead battery with a capacity of 760 ampere-hours, or at full voltage from the conductor-rail. Details of the control-equipment are given.

Experimental Electric Locomotive for High-Tension Single-Phase Electrification. (**Rly. Gazette* (*Lond.*) (*Electric Rly. Traction No. 81*), *139–141; 8 Dec. 1939.*)—At the end of 1938 the shop trials were completed of a C_0-C_0 electric locomotive for the 20,000-volt 50-cycle single-phase electrification of the Russian Railways. Alternating current is changed to direct-current by means of a mercury-arc rectifier with grid control. The output on the 1-hour rating is 2,040 kilowatts at 37 kilometres (23 miles) per hour, at which speed the tractive effort is 44,000 lb.

Manufacture of Armoured-Track Vehicles for War Service. (**Engineering*, 149, *33–34; 12 Jan. 1939*).—A description is given of the methods used in a factory producing tanks and machine-gun carriers. The factory, except for part of the machine-shop, is entirely new, and advantages were therefore enjoyed as regards freedom of selection of the most desirable layout. It is planned for the building of the machines to be split up into assemblies of reasonable dimensions and to minimize the number of different parts. The machine-shop houses about three hundred machine-tools, each provided with independent electric drive. Details are given of the engine-assembly, and of the sub-assemblies and tests.

Caterpillar Carriages for Cranes and Excavators. E. G. FIEGEHEN (**Engineering*, 148, *599–602; 1 Dec. 1939*).—The Author reviews the development of caterpillar tracks during the past 20 years, and their application to cranes and excavators. He discusses the power-unit, the track-belts, track-shoes, track loading, the effective bearing length of the track, the track-drive, and the overall efficiency of transmission. He also

describes steering and compensating gear, and discusses lubrication and the vertical clearance that should be available beneath a caterpillar carriage.

Electrical Equipment on Machine-Tools. P. B. GRAVES (***Elect. Engng., N.Y.*, 59 (*Transactions, 18–22*), *Jan. 1940*).—The Author describes recent applications of electrical equipment to machine-tools and indicates some of the problems which have arisen. His examples include a milling-machine and a grinding-machine. He discusses the controlling devices, the operation of the machines, the ease of change from 60-cycle to 50-cycle service, and the space required for mounting the electrical equipment. He concludes that by the use of motor drives and electric controls the performance of machine tools can be improved, and that the tools can be made simpler and easier to operate. He considers that many standard control devices are poorly qualified for machine-tool service, and should be re-designed for this more frequent and exacting duty.

Welding Trackwork by the Oxy-Acetylene Process on the London Midland & Scottish Railway. (**Rly. Gazette* (*Lond.*), 72, *88–91 ; 19 Jan. 1940.*)—An account is given of the methods of building-up worn switches and crossings, of bonding conductor- and running-rails for electric traction, and of repairing fractured buffer-stop rails.

The Manufacture of Wire for Use in Wire Ropes. A. B. DOVE (**Engng. J.*, 22, *520–524 ; Dec. 1939*).—The Author describes the process of " patenting", to remove from the rod material the differences in hardness caused by ingot structure and non-uniform cooling, and to produce a uniform structure (sorbite) which is best adapted to withstand the subsequent stresses of wire-drawing. He also describes the wire-mill operations and the changes of structure during drawing. He discusses the corrosion and hot galvanizing of steel, the fluxing operation, and the formation of dross.

Controlled Acceleration, Deceleration, and Regenerative Emergency Braking on Ward-Leonard Mine Hoists. H. FREEMAN (**J. Instn. Elect. Engrs.*, 85, *713–718 ; Dec. 1939*).—The Author describes his system for exercising control by purely electrical means, irrespective of the position of the driver's control-lever, and the use of the system for emergency regenerative braking. He describes in detail the control-exciter, the field-control resistance, the application of the control exciter in normal service and under emergency conditions, and the results obtained at Gifford's shaft, Champion Reefs, Mysore.

Norris Dam Construction Cableways. R. T. COLBURN and L. A. SCHMIDT, jun. (**Proc. Amer. Soc. Civ. Engrs.*, 65, *1733–1764 ; Dec. 1939*).—The two cableways used in the construction of the Norris dam, Tennessee,

together deposited 1,005,000 cubic yards of concrete and handled more than 68,000 tons of other materials. Each was designed for an 18-ton normal hook load and a 25-ton maximum load under reasonable overload conditions, and consisted of a track cable supported at each end on structural-steel travelling towers. The span, centre to centre of pins, was 1,928 feet 0½ inch; and centre to centre of back tower legs, 1,925 feet 6 inches. The hoisting-speed was 300 feet per minute; the lowering speed 400 feet per minute; the carriage travelling speed 1,200 feet per minute; and the tower traversing speed 50 feet per minute. Detailed descriptions of the design, construction, and operation are given.

MINING ENGINEERING.

The Maintenance of Inclination and Direction in Inclined Shafts. J. E. Metcalfe and A. R. Jones (**Bull. Instn. Min. Metall., No. 424, 14 pp.; Jan. 1940*).—The principles and methods described were developed by the Authors as the result of experimental work on two shafts in the Gold Coast colony. They describe the setting of grade-lines by two alternative methods and discuss the alignment and grading of sills, and state that by the application of their methods the plane of sills in each shaft has been kept uniform and at the correct inclination for considerable depths.

Deep Mine-Drainage Tunnel in the Cripple Creek District, Colorado. M. I. Signer (**Engng. Min. J.*, 140 (*12*), *34–36; Dec. 1939*).—The Carlton tunnel, now under construction, is the third tunnel driven in the district primarily for drainage purposes. It is 9 feet high, 8 feet wide, and 32,000 feet in length, whilst two branch tunnels, respectively 4,000 feet and 5,000 feet in length, will serve other mines. For practically its entire length the tunnel is in granite. Drainage 1,140 feet deeper than that now afforded by the second tunnel will be provided, allowing the ultimate depth of profitable mining to be increased. The Author describes the equipment and the driving operations. In October 1939 the daily rate of progress was 49·48 feet.

Reinforced-Concrete Pit-Props. W. H. Evans (**Colliery Guard.*, 159, *821–824; 8 Dec. 1939*).—The Author discusses materials and approximate costs, presenting the latter in the form of a Table and curves for three different concrete mixtures. He also deals with the reinforcement, reproduces illustrations of experimental spiral reinforcements, and emphasizes the importance of correct design and manufacture.

The Use of Timber Substitutes in Mines. T. E. B. Young and W. H. Sansom (**Colliery Guard*, 159, *902–905; 21 Dec. 1939*).—The Authors emphasize the necessity for the prevention of loss and of economy

in the use of mining timber under war conditions, and enumerate the advantages of the use of steel at the coal-face and elsewhere. They discuss steel supports at the coal-face, in roads, and in gateways, and present suggestions for general economies in the use of timber and for its recovery wherever possible.

The Formation of Injurious Gases on Firing Explosives. A. G. Suvoroff (*Gorny Journal* (*U.S.S.R.*), 8, *35–39 ; 1939*).—A series of mining explosives were detonated in a bomb and the volume of nitric oxide and carbon monoxide formed was determined. The explosives were detonated freely suspended, stemmed, and with and without the presence of iron ore, coal, shale, and other materials, in order to reproduce working conditions as closely as possible. Tabulated results are given.

Shaft Deepening at New Sharlston Colliery. J. S. Hayes (**Colliery Engng.*, 16, *421–426 ;* 17, *4–8 ; Dec. 1939 and Jan. 1940*).—A detailed description is given of the operations by which deepening to the extent of 200 yards was effected without a special winding-engine, housing, or staff ; without capstan engines and a multiplicity of ropes in the shaft ; without an independent ventilating fan ; and without elaborate bricking-scaffolding. The average rate of progress was 1¼ yard of finished sinking and bricking per week—excluding the time occupied in forming the pit-bottom ; but the Author states that this rather slow progress was from choice.

Borehole Temperatures in the Transvaal and Orange Free State. L. J. Krige (*Proc. Roy. Soc.* (*A*), 173, *450–474 ; 29 Dec. 1939*).—Temperatures were measured in five deep boreholes which pass through dolomite, Ventersdorf lava, Witwatersrand quartzite, intrusive dibase, and small thicknesses of other rocks. The geometric step (increase in depth per degree C.) varies over wide ranges, its mean values being highest in the dolomite and lowest in the lava. As a rule it is small above the water-table, especially in the leached dolomite, and generally largest immediately below this level.

Canadian Mine Hoists. H. V. Haight and G. M. Dick (**Mech. Engng., N.Y.*, 61, *885–891 ; Dec. 1939*).—The Authors classify mine hoists under three headings, namely, main hoists, auxiliary hoists, and slushing hoists utilized for scraping and loading. They discuss the design and operation of the various types, and give detailed descriptions of several large hoists installed at mines in Ontario, Quebec, and Nova Scotia.

Recent Research on Coal. D. J. W. Kreulen (*Chem. Weekblad*, 36 *; 30 Dec. 1939*).—The results of recent investigations on the properties of coal are considered collectively on a more or less mathematical basis. An attempt is made to correlate weathering, coking, and combustion

phenomena with certain chemical and physical constants. One fact appearing from the results is that coal does not represent a single stage of coalification, but a series of at least two consecutive stages.

Determining the Total Sulphur in Coal and Coke by a Reduction Process in conjunction with a Rapid Analytical Method. W. Mantel and W. Schreiber (*Glückauf*, 75, *929–936 ; 2 Dec. 1939*).—In the method developed by the Author, complete gasification occurs in the presence of water-vapour and catalyzers, through oxidation of the carbon to monoxide and dioxide. The hydrogen separated from the water-vapour promotes the formation of ammonia and represses its dissociation. The idea that a similar principle might be adopted in determining the total sulphur in the form of hydrogen sulphide led to the investigations discussed. A method was evolved which enables the total sulphur in all coals and cokes to be estimated to within 0·03 per cent. in 20–30 minutes. This method is described in detail.

Firedamp: its Occurrence in Mines and Possible Utilization. J. I. Graham (**Proc. S. Wales Inst. Engrs.*, 55, *326–357 ; 11 Jan. 1940*).—The Author presents the results of experiments made on a large number of specimens of coal, each from a freshly-exposed coal-face, to determine the volume and pressure of gas in the coal. He concludes that methane may be present in anthracite, as worked, to the extent of 600 cubic feet per ton, and that the pressure of the gas in the coal may attain 110 lb. per square inch. Increase of temperature produces a marked increase in pressure. High pressures with smaller volumes have also been encountered in other seams. The Author discusses the national loss of fuel in the escape and dilution with air of methane underground, and the possibility of utilizing pure methane as a fuel for motor-cars.

The Determination of the Firedamp-Content in Mine Air. T. D. Jones and W. L. Gyles (**Proc. S. Wales Inst. Engrs.*, 55, *290–311 ; 11 Jan. 1940*).—The Authors describe in detail tests made in the laboratory and underground on two types of gas-detector, an American methane detector, and the Montluçon firedamp-detector. The results are tabulated, and the conclusion is drawn that these instruments, if maintained and handled properly by competent persons, will yield accurate results, and that their introduction will effect a considerable saving in time and money as the result of the reduction in the number of air-samples to be analysed in laboratories.

Double-Screen Protection for Trailing Cables: Elimination of Open Sparking. (**Iron Coal Tr. Rev.*, 139, *687 ; 17 Nov. 1939.*)—During a cutting shift at a colliery in South Wales an accident occurred to a trailing cable containing two concentric screens, the outer one of which was

earthed. A low-potential supply is fed to the inner screen and relays are connected in series so that a metallic connexion between the two screens will immediately trip the gate-end contactor. The accident consisted of a fall of stone which cut through two screens and one power core and partly into the other power cores. Although the full power was on at the time, and the coal-cutter was working, microscopical examination of the cable did not reveal any sign of sparking, either between the cores or from core to earth, indicating that the power had been cut off before the cores were damaged. The mishap described is considered to form a practical test of considerable value.

Granite Quarrying: Electrical Methods at Penmaenmawr, North Wales. (**Elect. Rev., London*, 126, *3–6; 5 Jan. 1940.*)—The electrical installation includes two hundred motors, the largest being of 400 horse-power, and the annual power-consumption amounts to about 4½ million kilowatt-hours. Power is received at 20 kilovolts and is transformed to 2,000 volts and 500 volts at four substations. The higher voltage is required for excavators, primary mills, compressors, winches, etc., and the lower voltage for secondary mills, screens, and conveyors. Subsidiary transformers give 100-volt current for lighting and 25-volt current for hand-lamps. Details of all the equipment are given in the article.

NOTE.—The Institution as a body is not responsible either for the statements made, or for the opinions expressed, in the Papers and Abstracts published.

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NOTE.—*Pages [1] to [14] can be omitted when the Journal is bound in volume form.*

NOTICES

No. 5, 1939–40

MARCH, 1940.

MEETINGS, SESSION 1939–40.

ORDINARY MEETINGS.

The following subjects will be brought forward for discussion on the dates indicated below :—

Mar. 19. **"The Sewage-Disposal of Delhi."** J. A. R. Bromage, M. Inst. C.E.

Apr. 23. **"Remodelling of the Assiut Barrage, Egypt."** J. E. Bostock, O.B.E., M. Inst. C.E.

May 7.* **"Cliff-Stabilization Works in London Clay."** J. Duvivier, B.Sc. (Eng.), M. Inst. C.E.

Brief Abstracts of these Papers appeared on pp. [15] *et seq.* of the February Number of the Journal.

*** NOTE :—The date of this meeting has been changed from that given in the February Journal and on the card of meetings.**

ROAD ENGINEERING SECTION.

Apr. 2. (5.30 p.m.) "The Engineer's Part in the Promotion of Road Safety", by F. A. Rayfield, Assoc. M. Inst. C.E.

A brief synopsis of this Paper is printed on p. [12].

JAMES FORREST LECTURE.

The James Forrest Lecture, on "New Materials for Old", will be delivered by Mr. E. V. Appleton, M.A., D.Sc., LL.D., F.R.S., on Tuesday, 28 May, at 5.30 p.m.

A

ANNUAL GENERAL MEETING.

The Council, acting on the powers conferred upon them, have decided that the Session shall end on the 30th May, and that the Annual General Meeting shall be held on the 11th June at 5.30 p.m., unless otherwise announced.

SPECIAL ANNOUNCEMENTS.

MILITARY SERVICE.

EMERGENCY COMMISSIONS IN R.E. TRANSPORTATION.

The War Office invites members of The Institution who have had experience in railway surveying or railway construction and who are between 25 and 40 years of age to submit their qualifications with a view to being granted Emergency Commissions through the Army Officers' Emergency Reserve. Members who are desirous of applying and who have obtained the necessary permission to offer their services (where such permission is required) should apply as soon as possible to the Secretary of The Institution for the Army form.

The fact that a member has lodged a form with the Central Register of the Ministry of Labour does not debar him from volunteering in response to this invitation from the War Office. Members who have already lodged applications for registration in the Reserve should not apply for a second form.

ARMY OFFICERS' EMERGENCY RESERVE.

The attention of members who desire to register in this Reserve is directed to the announcement on p. [2] of the February Journal.

NATIONAL SERVICE (ARMED FORCES) ACT, 1939.

A notice regarding registration at Local Employment Exchanges when age-groups are called up under this Act appears on p. [3] of the February Journal.

GENERAL ANNOUNCEMENTS.

INSTITUTION LUNCHEON.

It has been arranged to hold a Luncheon in place of the usual Annual Dinner of The Institution. This will take place at the Savoy Hotel, Strand, on the 19th April. Full particulars are given on the accompanying leaflet issued to home Corporate Members and Associates. The Right Hon. Sir John Anderson, G.C.B., G.C.S.I., G.C.I.E., Secretary of State for the Home Department and Minister of Home Security, will be the principal guest.

VISITORS AT INSTITUTION MEETINGS.

Members and Students are reminded that, under the By-Laws, they may bring visitors to Institution Meetings upon production of a signed card of introduction, according to a form provided. The Secretary will be pleased to forward such cards to members upon request.

MAURICE FITZGERALD WILSON.

At the Ordinary Meeting on the 20th February, Mr. M. F-G. Wilson was elected an Honorary Member in recognition of his valued services to the profession and as a Member of Council. During his 56 years' membership Mr. Wilson has presented Papers to The Institution for which he was awarded a Stephenson Medal and a Telford Premium. He was elected a Member of Council in 1928 and a Vice-President in 1937.

ENGINEERING JOINT COUNCIL.

The Council have renominated Dr. David Anderson and Mr. W. T. Halcrow, Members of Council, as representatives of The Institution on the Engineering Joint Council for the Session 1940–1941.

THE INSTITUTION BUILDING.

Members and Students are reminded that coloured prints of a drawing of the Institution building (original in colours by H. Rushbury, R.A.), may be purchased. The charge is half a guinea a copy; and a limited number, signed by the artist, are available at one guinea each: 1*s.* extra for packing and postage. The prints (20 inches by 13 inches without the border) are mounted ready for framing. Particular attention has been paid to obtain a really artistic picture. A copy may be seen at the Institution, and specimens were forwarded to the Honorary Secretaries of Local Associations for viewing by members in their areas.

The profit from the sale will be devoted to the Benevolent Fund Homes of The Institution, and it is, therefore, hoped that such a cause will result in a large number of these prints being purchased.

Remittances should be made payable to "The Institution of Civil Engineers."

LENGTH OF PAPERS PRESENTED TO THE INSTITUTION.

The following extract from the "Memoranda for the Guidance of Authors" is published for information :—

"It is of great importance that Authors . . . should confine themselves as far as practicable to those features of their subject which are novel and likely to be of interest and value to their fellow engineers.

"It has been found that Papers of 5,000 words and less have dealt adequately with one aspect of a subject and, when discussed, have given rise to an effective discussion. A Paper of 15,000 words is long enough for the presentation of any subject to The Institution, and if this limit is exceeded, it will be doubtful if the Paper can be accepted for publication except in an abridged form, as the space available in the Journal is limited."

The Council invite Original Communications on suitable subjects of engineering interest. For approved Papers the Council may award premiums, arising out of endowments instituted for the purpose, details of which were given on pp. [6] *et seq.* of the November 1939 Journal. No distinction will be made, in the adjudication, between Papers received from members of The Institution and others in connexion with the award of premiums, except where eligibility is limited by the directions of the donors.

MSS. should be submitted in duplicate, and further memoranda for the guidance of Authors in the preparation of Original Communications are contained in a pamphlet, copies of which can be obtained on application to the Secretary.

THE JOURNAL.

The remaining publication dates of the Journal for Session 1939–40 are the 15th April, June, and October, 1940.

READING ROOMS AND LIBRARY.

The Reading Rooms and Library are open during office hours (9.30 to 5.30 : Saturdays 9.30 to 1) and on evenings when Institution meetings are held. An air-raid shelter accommodating some 50 persons is available for members who may be on business in the building during an air raid, and for the Institution Staff.

The normal loan service of books from the Library is also available for the use of members.

NOTICE RELATING TO THE JANUARY, 1940, JOURNAL.

In connexion with the Paper on "Activities for the Improvement of the Social and Economical Status of the Members of the Civil Engineering Profession", published in the Journal for January, 1940, attention has been drawn to the possibility of an incorrect inference being drawn from the reference to the Engineers' Guild on p. 192, by reason of the expression "action on Trade Union lines" having been used in the same sentence. This expression was used to denote activities primarily directed to the "benefit of the profession" as distinct from the "advancement of engineering science."

It is well known that the Council of the Engineers' Guild has always declared that the Guild shall not be a Trade Union, and that all the activities shall be of a strictly professional character, and Sir Clement Hindley wishes to take this opportunity of pointing out that any impression to the contrary which might be drawn from those words is not warranted if they are read with their context.

TRANSFERS, ELECTIONS, AND ADMISSIONS.

Since the 23rd January, 1940, the following elections have taken place :—

Meeting.	*Honorary Member.*	*Associate Members.*
20 February, 1940.	1	16

and during the same period the Council have transferred ten Associate Members to the class of Members, and have admitted forty-four Students.

DEATHS AND RESIGNATIONS.

The Council have received, with regret, intimation of the following deaths and resignations :—

Deaths.

CROMPTON, Rookes Evelyn Bell, C.B., F.R.S. (*E. Member* 1886. *E. Hon. Member* 1934.) Col. Electrical Engrs. R.E. (T.). (*Former Member of Council.*)	*Honorary Member.*
BAILEY, Arthur Stowey, O.B.E. (E. 1894. T. 1904.)	*Member.*
BOATH, Robert. (E. 1891. T. 1910.)	„
CHATHAM, William, C.M.G. (E. 1885. T. 1897.)	„
CUSHING, William Channing. (E. 1915.)	„
MACLEAN, James Borrowman, C.B.E. (E. 1918.)	„
MILLS, William Burton Saville. (E. 1884. T. 1909.)	„
ROSS, William McGregor, M.Sc., B.A., B.E. (E. 1904. T. 1913.)	„
SANDBERG, Oscar Fridolf Alexander, O.B.E. (E. 1905. T. 1919.)	„
WEIR, William Park. (E. 1894. T. 1911.)	„
WHITE, Alfred Hale, M.A. (E. 1913. T. 1928.)	„
BAMFORD, Charles Frederick. (E. 1892.)	*Associate Member.*
BECK, Ernest George. (E. 1907.)	„ „
BIRKETT, Robert. (E. 1883.)	„ „
BLENKINSOP, Martin Alfred. (E. 1903.)	„ „
BROWN, Edward Johnson. (E. 1887.)	„ „

DEANS, Alexander Robertson. (E. 1924.)	*Associate Member.*
DENHAM, Henry Mangles. (E. 1895.)	" "
DICKINSON, William, M.C. (E. 1923.)	" "
PRICE, Hubert. (E. 1930.)	" "
THORPE, Harold Gunson. (E. 1924.)	" "

RESIGNATIONS.

CRESSWELL, Herbert Augustine. (E. 1905. T. 1921.)	*Member.*
HOPKINSON, Sir Frederick Thomas, K.B.E. (E. 1889. T. 1907.)	"
BOLLAM, William Chris. (E. 1909.)	*Associate Member.*
JEFFERIS, Charles Edward. (E. 1912.)	" "
STALLARD, Sidney, C.B.E., D.S.O. (E. 1895.)	" "
WHYTE, Charles Edward Montgomery. (E. 1910.)	" "
ANTILL, James Macquarie, B.E. (A. 1936.)	*Student.*
MOODY, Neil Malcolm Rowland. (A. 1938.)	"

RECENT ADDITIONS TO THE LIBRARY.

[Journals, Proceedings of Societies, British Standard Specifications, etc., are not included.]

AIRCRAFT. AIR MINISTRY, METEOROLOGICAL OFFICE. Professional Notes No. 82. "Ice Accretion on Aircraft." Revised 1939. H.M.S.O. No Price.

AIR FILTERS. ROWLEY, F. B. and R. C. JORDAN. "Factors Affecting the Performance and Rating of Air Filters." 1939. Bulletin No. 16. University of Minnesota Engineering Experiment Station. Minneapolis. No Price.

ALLOYS. *See* METALS.

ASPHALT. *See* CEMENTS.

ATLASES. *BARTHOLOMEW, J. "The Oxford Advanced Atlas." 5th ed. 1936. Oxford University Press. 10*s.* 6*d.*

BUILDING AND BUILDINGS. WALKER SMITH, D., and H. A. CLOSE. "The Standard Form of Building Contract (1939)." 1939. Federated Employers Press. 10*s.* 6*d.*

CANNING. WOODCOCK, F. H., and W. R. LEWIS. "Canned Goods and the Canning Industry." 1938. Pitman. 7*s.* 6*d.*

CARBON MONOXIDE. D.S.I.R. Methods for the Detection of Toxic Gases in Industry. Leaflet No. 7. "Carbon Monoxide." 1939. H.M.S.O. 1*s.* 6*d.*

The industrial conditions under which dangerous concentrations of the gas may develop are reviewed, the symptoms indicating carbon-monoxide poisoning are indicated, and the standard method developed for detection of the presence of the gas is described.

CEMENTS. LANG, F. C., and T. W. THOMAS. "Laboratory Studies of Asphalt Cements." 1939. University of Minnesota Engineering Experiment Station, Minneapolis. Bulletin No. 15. No Price.

CHEMICAL ANALYSIS. *See* METALS.

COAL MINING. RICE, G. S., and I. HARTMANN. "Coal Mining in Europe." 1939. (U.S. Bureau of Mines Bulletin 414.) Supt. of Documents. Washington. 50 cents.

—— U.S. BUREAU OF MINES. Reports of Investigations Nos. 3462–5 and I.C. Nos. 7087 and 7089 deal with Coal Dust, Electrical Equipment, Rock Dusting and Ignition of Firedamp. 1939. U.S. Bureau of Mines, Washington.

CONCRETE, D.S.I.R. Building Research Technical Paper No. 21. Studies in Reinforced Concrete. IV. "Further Investigations on the Creep or Flow of Concrete under Load." 1939. H.M.S.O. 1*s*.

Results obtained from prolonged loading tests on small cylinders of plain concrete are given, and also results from reinforced-concrete columns and beams.

—— BUILDING INDUSTRIES NATIONAL COUNCIL. "Code of Practice for the Use of Reinforced Concrete in the Construction of Buildings." 1939. B.I.N.C., 85 Gloucester Place, W.1. 1*s*. 3*d*.

CORROSION. HUDSON, J. C. "The Corrosion of Iron and Steel, being a general account of the work of the Corrosion Committee of the Iron and Steel Institute and the British Iron and Steel Federation." 1940. Chapman & Hall. 18*s*.

This book forms a general survey of the results of the first 10 years' work of the Committee, with a discussion of their practical implications. Detailed recommendations are made for the protection of structural iron and steel by means of paint. The atmospheric corrosion of wire is dealt with, and the present state of knowledge of soil-corrosion is surveyed.

DAMS. U.S. BUREAU OF RECLAMATION. Boulder Canyon Project. Final Reports. Part 5.—Technical Investigations. Bulletin 3. "Model Tests of Boulder Dam." 1939. Bulletin 4. "Stress Studies for Boulder Dam." 1939. The Bureau, Denver, Colorado. 2 dollars each.

These bulletins form part of a series prepared to record the history of the project, the results of technical studies and experimental investigations, and unusual features of design and construction.

DICTIONARIES. *"CASSELL'S German and English Dictionary." Revised ed. by K. Breul. 1939. Cassell. 12*s*. 6*d*.

—— *See also* METALS.

DIESEL ENGINES. SQUIRE, C. E. "Springs for Large Diesel Engines." 1939.

—— "Symposium on Running Gear for Diesel Engines." 1939. Diesel Engine Users' Assoc., 56 Victoria Street, S.W.1. 7*s*. each.

DORSET. DAVIES, G. M. "The Dorset Coast: A Geological Guide." 1935. Murby. 6*s*. 6*d*.

ECONOMICS. LESTER, B. "Applied Economics for Engineers." 1939. Chapman & Hall. 24*s*.

This book is intended to provide the student of engineering with an introduction to the practical aspects of economics, based upon conditions and problems likely to be encountered in the practice of the profession.

ENGINEERING. HOLMSTROM, J. E. "Records and Research in Engineering and Industrial Science." 1940. Chapman & Hall. 15*s*.

This book is intended to serve as a guide to the many and varied sources of technical knowledge available in publications, translations, abstracts, indexes, libraries, and institutions throughout the world, with clues to where detailed and specific information may be sought.

—— *Mechanical World*. "Engineering Questions and Answers." Vol. 2. Emmott & Co. 1939. 6*s*.

—— *PARSONS, W. B. "Engineers and Engineering in the Renaissance." 1939. Williams & Wilkins. Baltimore. 8 dollars.

—— *PENDRED, L. St. L. "Kempe's Engineer's Year Book, 1940."

—— 1940. Morgan Bros. 31*s*. 6*d*.

—— *See also* MODEL ENGINEERING.

EXCAVATION. *INGERSOLL-RAND Co. "Modern Methods for Scraper Mucking and Loading." 1939. 11 Broadway, New York. 3 dollars.

FOOD. D.S.I.R. "Report of Food Investigation Board, 1938." 1939. H.M.S.O. 4*s*. 6*d*.

FOUNDRIES. LAING, J., and R. T. ROLFE. "Manual of Foundry Practice." 2nd ed. 1938. Chapman & Hall. 18*s*.

GAS. *"*Gas Journal* Calendar and Directory, 1940." 1940. W. King. 21*s*.

In addition to a comprehensive directory of gas undertakings in Great Britain, Eire, and the Dominions, details of gas works practice are presented, with general information and useful reference Tables.

GAS SUPPLY. COE, A. "The Science and Practice of Gas Supply." Vol. 3. 1939. British Commercial Gas Assoc. 42*s*.

GEOLOGY. *See* DORSET.

HARBOURS. *HUGHES, B. C. "History of Harwich Harbour, 1863–1939." 1939. Clerk, Conservancy Board, Harwich. 21*s*.

HYDRAULICS. KING, H. W. "Manning Formula Tables. Vol. 2. Flow in Open Channels." 1939. McGraw-Hill. 33*s*.

INDUSTRIAL SCIENCE. *See* ENGINEERING.

IRAQ. GOVERNMENT OF IRAQ. Ministry of Economics and Communications, Iraq Geological Department. Publication No. 1. "Water Supplies in Iraq," by W. A. Macfadyen. 1938. Government Press, Baghdad. 5*s*.

IRON. *See* CORROSION and STEEL.

LEATHER. MOORE, J. W., and F. C. VILBRANDT. "Air Burn Control in Drying Heavy Leather." Virginia Polytechnic Institute Engineering Experiment Station. 1939. Bulletin No. 41. Blacksbury, Va. 25 cents.

MACHINERY. *OBERG, E., and F. D. JONES. *Ed.* "Machinery's Handbook for Machine Shop and Drawing Office. 10th ed. Machinery Pub. Co. 1939. 38*s*.

MANAGEMENT. HEYEL, C. "Human Relations Manual for Executives." 1939. McGraw-Hill. 12*s*. 6*d*.

The Author has made a careful selection of material illustrating the principles that have resulted from studies of the human factor in industry. The ideas advanced are essentially simple and can be applied without elaborate equipment or the services of highly specialized administrators.

MATHEMATICS. BURINGTON, R. S., and C. C. TORRANCE. "Higher Mathematics with applications to Science and Engineering." 1939. McGraw-Hill. 33*s*.

—— HARDY, G. H., and E. M. WRIGHT. "Introduction to the Theory of Numbers." 1938. Clarendon Press. 25*s*.

METALS. *CAMM, F. J. *Ed.* "A Dictionary of Metals and their Alloys." 1940. G. Newnes. 5*s*.

The names of metals and alloys are arranged alphabetically, with their compositions and characteristics. Separate sections of the book deal with hardening, case-hardening and tempering, electro-plating, polishing, chemical colouring, metal-spraying, and rust-proofing.

—— GREGORY, E., and W. W. STEVENSON. "Chemical Analysis of Metals and Alloys." 1937. Blackie. 16*s*.

—— MARSHALL, P. "Metal Working Tools." 1939. Percival Marshall. 1*s*. 6*d*.

MICROMETERS. MARSHALL, A. W., and G. GENTRY. "Micrometers, Slide Gauges and Calipers." 1939. Percival Marshall. 1*s*. 6*d*.

MODEL-ENGINEERING. BEAL, E. "Scale Railway Modelling To-day." 1939. A. and C. Black. 7*s*. 6*d*.

NOISE. D.S.I.R. Building Research Special Publication No. 26. "The Reduction of Noise in Buildings." 1939. H.M.S.O. 1*s.*

The Report presents the results of an intensive programme of research carried out jointly by the National Physical Laboratory and the Building Research Station, and records certain broad principles which have emerged from the work.

NUMBERS, THEORY OF. *See* MATHEMATICS.

ORGAN-BUILDING. LEWIS, W. and T. "Modern Organ Building." 3rd ed. 1939. W. Reeves. 15*s.* 6*d.*

PERMANENT-WAY. "COLE'S Permanent Way." 10th ed. revised by Col. Sir Gordon R. Hearn. 1940. Spon. 10*s.* 6*d.*

The tenth edition of this standard work has been almost entirely recast and rewritten, to indicate modern methods demanded by heavier loads and increasing speeds. It deals with all gauges and gives examples of practice from many parts of the world.

—— RENCH, W. F. "Practical Trackwork." 1926. General Publishing Co. 7*s.* 6*d.*

—— RENCH, W. F. "Simplified Curve and Switch Work." 4th ed. 1930. Simmons-Boardman. 10*s.*

PILES. *AMERICAN SOCIETY OF CIVIL ENGINEERS. "Timber Piles and Construction Timbers." 1939. (Manual of Engineering Practice No. 17.) A.S.C.E. 33 West 39th Street, New York. 4*s.*

PORTS. DE JOLY, G., and OTHERS. "Travaux Maritimes. Tome 3. Ouvrages, Intérieurs et Outillage des Ports." 1940. Dunod. 165 francs.

PRICE-BOOKS. *"SPON'S Architects' and Builders' Pocket Price Book, 1940." 1940. Spon. 6*s.*

In view of present conditions, the 1939 prices have been retained as a standard basis of values, and "Conversion Tables" are given by means of which the normal standard pre-war rates may be corrected to actual requirements.

PRODUCER-GAS. MINES DEPARTMENT. "Report of the Committee on the Emergency conversion of Motor Vehicles to Producer Gas." 1940. H.M.S.O. 9*d.*

RAILWAYS. *See* MODEL-ENGINEERING, PERMANENT-WAY.

ROADS AND TRACKWAYS. D.S.I.R. "Report of the Road Research Board for Year ending 31st March, 1939." 1939. H.M.S.O. 3*s.* 6*d.*

—— TYLER, F. C. "The Geometrical Arrangement of Ancient Sites. A development of the 'Straight Track' Theory." 1939. Simpkin Marshall. 2*s.* 6*d.*

SPRINGS. *See* DIESEL-ENGINES.

STEEL. DEARDEN, J. "Iron and Steel To-day." 1939. Oxford University Press. 4*s.* 6*d.*

—— SCHEER, L. "What is Steel? An Introduction for Everyman to the Science of Steel." 3rd revised ed. Translated from the German by F. L. Meyenberg, Macdonald & Evans. 1939. 6*s.*

—— SKELTON, R. A., & Co. "Structural Steel Handbook No. 22." 1940. 10*s.*

—— YOUNG, H., & Co. "Modern Structural Steelwork." 1940. No price.

STORES AND STOREKEEPING. BURTON, J. H. "Stores Accounts and Stores Control." 3rd ed. 1937. Pitman. 10*s.* 6*d.*

STRUCTURES. WILBUR, J. B. "Structural Analysis in Laboratory Research, 1938–9." 1939. Serial No. 68. Massachusetts Institute of Technology, Cambridge, Mass. No price.

—— *See also* STEEL.

Switches. *See* Permanent-Way.

Tests and Testing Apparatus. Hounsfield, L. H. "Commercial Testing. Part I. Notched Bar Testing." 1939. Author, 81 Morlands Road, Croydon. 3*s* 6*d*.

The Author summarizes the results obtained and the conclusions drawn by a large number of investigators in the field of notched-bar testing, and supplements this information by giving the results of his own experimental work in directions where considerable differences of opinion appeared to exist.

Timber. Bateson, R. G. "Timber Drying and the Behaviour of Seasoned Timber in Use." 1938. Lockwood. 10*s*. 6*d*.

—— Henderson, F. G. "Timber; its Properties, Pests and Preservation." 1939. Lockwood. 9*s*. 6*d*.

—— *National Lumber Manufacturers' Assoc. "Wood Structural Design Data." Vol. I and Supps. 1–7. 1939. N.L.M.A. Washington. 1 dollar 75 cents.

War. *Fay, Sir S. "The War Office at War." 1937. Hutchinson. 10*s*. 6*d*.

Water Purification. West Virginia University Engineering Experiment Station. Technical Bulletin No. 14. "Selected Papers from the 13th Annual Conference on Water Purification." 1939. Morgantown, W. Va.

Water-Supply. *See* Iraq.

Welding. British Oxygen Co. "Handbook for Oxy-Acetylene Welders." 3rd ed. 1939. B.O.C., Thames House, Millbank, S.W.1. 3*s*. 6*d*.

—— Child, I. K. "Principles of Electric Arc Welding." 1939. Draughtsman Publishing Co. 2*s*.

—— Kilburn, W. L. "Copper and Bronze Welding." 1939. B.O.C. 5*s*.

—— Partington, E. B. "Chemical Plumbing, Leadburning and Oxy-Acetylene Welding." 1932. B.O.C. 5*s*.

Wood. *See* Timber.

(* *The foregoing books, with the exception of those marked with an asterisk, may be borrowed from the Loan Library.*)

LOCAL ASSOCIATIONS.

MEETINGS.

The following meetings have been arranged :—

Bristol and District Association.

Apr. 11. "The Dragline Excavator", by William Barnes.

North-Western Association.

Mar. 20. "The Treatment of Water by Ozone", by M. T. B. Whitson, B.Sc., Assoc. M. Inst. C.E.

Apr. 17. Annual General Meeting.

Northern Ireland Association.

Apr. 8. Annual General Meeting and "The Institution Research into the Deterioration of Structures Exposed to Sea-action", by Professor A. H. Naylor, M.Sc., M. Inst. C.E.

REPORTS.

Birmingham and District Association.

A joint meeting with the West Midland District of the Institution of Municipal and County Engineers was held on Friday, 26 January, when Mr. E. H. Ford, M. Inst. C.E., read a Paper on " The Coventry By-pass Road."

Edinburgh and District Association.

On Wednesday, 14 February, a Paper on " Modern Developments in Excavating Machinery " was read by Mr. A. H. Wade.

Glasgow and District Association.

On Friday, 16 February, Mr. James Williamson, M. Inst. C.E., read a Paper on " Hydro-Electric Development in Britain and the Empire."

Northern Ireland Association.

On Monday, 29 January, Mr. J. J. Hartley, M.Eng., M.Sc., Assoc. M. Inst C.E., read a Paper on " The Sub-Soils of Belfast and District."

Southern Association.

The following meetings have been held :—Thursday, 18 January, at Portsmouth, when Mr. F. W. Taylor, Assoc. M. Inst. C.E., read a Paper on " Modern Methods of Plan Reproduction " ; Thursday, 25 January, at Southampton, when a discussion on " The Contractor in Civil Engineering " was introduced by Mr. W. E. Reed, Assoc. M. Inst. C.E. ; Thursday, 8 February, at Chichester, when a Paper on " Roads and Road Policy " was read by Mr. Arthur Floyd, B.Sc., Assoc. M. Inst. C.E.

Yorkshire Association.

The Annual Dinner of the Association was held at the Hotel Metropole, Leeds, on Thursday, 25 January, when there was an attendance of 57 members and guests. On Saturday, 27 January, at a joint meeting with the local branches of the Institution of Structural Engineers and the Institution of Municipal and County Engineers, a Paper on " Geological Faults of Yorkshire " was read by Professor R. G. S. Hudson, D.Sc., F.G.S.

ASSOCIATION OF LONDON STUDENTS.

A Meeting of this Association was held on Wednesday, 31 January, at 6 p.m., Mr. W. T. Halcrow, Member of Council, taking the Chair. About fifty-four Students attended the Meeting, at which an abridged version of a Lecture on the Boulder dam was read. The Lecture was illustrated by lantern-slides, and was followed by the exhibition of the official film produced by the United States Bureau of Reclamation depicting the various stages of the work.

The Chairman expressed his pleasure at the large attendance. He stated that a desire had been expressed for an Informal Meeting to be held at an early date, and he would like to have an expression of opinion from those present. The suggestion was approved with acclamation, and the Honorary Secretary was, therefore, requested to make the necessary arrangements. At the conclusion of the Meeting a vote of thanks to the Chairman was passed. In acknowledging this, Mr. Halcrow observed that he was always happy to attend such meetings. The Students were the coming generation of engineers—future Members of Council and future Presidents of The Institution—and although works of the magnitude described were not usual practice with British engineers, the profession they had chosen was one in which each new work brought its own problems and interest.

The Joint Dance with the Students of the Institutions of Mechanical and Electrical Engineers was held on Saturday, 24 February, at Baltic Hall, Leadenhall Street. About 320 students and ladies took part.

ROAD ENGINEERING SECTION.

The following Paper will be brought forward for discussion on the 2nd April, and will be published, with a report of the discussion, in the June Journal. Members wishing to obtain advance copies of the Paper should apply to the Secretary, quoting the number of the Paper.

Road Paper No. 2.

"The Engineer's Part in the Promotion of Road Safety."

By Frank Alan Rayfield, Assoc. M. Inst. C.E.

The Author makes a comparison between conditions in Great Britain and those in other countries, and considers the extent to which road conditions are the main cause of accidents. He refers to the influence of road layout, and to the segregation of traffic, and discusses the advantages of motor roads in that respect. He concludes by mentioning briefly certain general measures for obtaining increased road safety.

VISIT OF SIR LEOPOLD SAVILE, K.C.B., VICE-PRESIDENT, to AUSTRALIA and NEW ZEALAND in 1939.

It is not very often that members of The Institution on the opposite sides of the world have the opportunity of meeting. Last summer Sir Leopold Savile, K.C.B., Vice-President, visited Australia on behalf of his firm for the purpose of advising the Commonwealth Government upon the choice of a site for a graving dock to accommodate capital ships. He was able to take advantage of the opportunity to have the pleasure of meeting many of the members, and of attending meetings of two of the Advisory Committees.

In nearly every port which he was asked to visit Sir Leopold received a welcome from members of The Institution. On the day before his arrival at Melbourne he received a telegram from the Chairman and Members of the Victorian Local Association welcoming him to Australia. On his arrival at Melbourne he was met by Mr. L. R. East, Chairman, and Mr. W. D. Chapman, Secretary, of the Victorian Advisory Committee and Local Association, and although he was unavoidably prevented from accepting the hospitality they offered him, he attended a meeting of that committee.

In Sydney he was present at a meeting of the New South Wales Advisory Committee, and a lunch was given by the committee at which Mr. K. T. McKay, Chairman, Mr. Jones, Secretary, and ten members were present. It is interesting to note that one matter discussed, both at the meeting of the Advisory Committee in New South Wales and at that in Victoria, was the possibility of more Australian engineers joining The Institution. Sir Leopold mentioned that he felt sure that the Council would carefully consider any suggestions made by the Local Association and Advisory Committees. In Adelaide Sir Leopold dined with the members of the Local Association of South Australia.

In Auckland he had the opportunity of meeting Mr. Drummond Holderness, Member of Council of The Institution and Chairman of the New Zealand Advisory Committee, and attending a lunch at which he met other members of The Institution in New Zealand.

In addition, however, to that of the members of The Institution, Sir Leopold also received a warm welcome from the Institution of Engineers, Australia, which is one more indication of the very cordial relations which exist between the two Institutions.

On arrival in Colombo he received a cable of welcome from the Institution of Engineers, Australia, extending an invitation to lunch in Sydney. At Fremantle he was met and welcomed to Australia on behalf of that Institution by Mr. W. A. McCullough, Chairman of the Perth Division of the Institution of Engineers, Australia, and by Mr. G. Drake Brockman, M.C., Vice-President of that Institution.

At Sydney Sir Leopold was welcomed by Mr. A. F. Julius, Chairman of

the Institution of Engineers, Australia, and was the guest of honour at a lunch given by the Sydney Division Committee, at which, in addition to the welcome extended by the Chairman, a welcome was also extended from the Government of New South Wales by the Hon. Colin Sinclair, Minister for Lands, and by the late Rear-Admiral W. N. Custance, C.B., R.A.N. Sir Leopold presented the Division with a replica of the original Minute-Book of the Society of Civil Engineers, established in 1771.

In Adelaide Sir Leopold, at the invitation of the Chairman, Mr. A. R. Shepley, attended a General Meeting of the Adelaide Division of the Institution of Engineers, Australia, and in Hobart a welcome was extended to him on behalf of the Tasmanian Division of the Institution of Engineers, Australia, by the Chairman, Mr. H. M. Bamford.